PROBLEM ANALYSIS
FOREST FIRE PROTECTION IN CALIFORNIA

CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION

BERKELEY, CALIFORNIA
1941

FOREST SERVICE
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BERKELEY, CALIFORNIA

RS-CAL
RESEARCH PROGRAM
Problem Analyses
Fire

March 19, 1941

Regional Forester
U. S. Forest Service
Post Office Building
Portland, Oregon

Dear Sir:

For your information there is enclosed a copy of "A forest fire protection problem analysis for California."

Forest fire protection research at the California Forest and Range Experiment Station has two functions. The first is to assist the fire control agencies within the Region in the solution of immediate pressing problems. The second is to carry forward a long-term program of basic research aimed at the betterment of all phases of fire-control practice.

This problem analysis has been prepared to serve as a basis for keeping this long-term program as objective as possible and to serve as a basis for correlating the work of this Station with that being carried on elsewhere. It is aimed specifically at the selection of a small number of problems from all those confronting forest administrators in California. It is our belief that Research, with its limited resources, can make its greatest contribution in terms of better fire protection by concentrating on these few problems. Beyond a broad classification of the types and rough amounts of study needed for solution of the problems, no attempt has been made here to prescribe all the detailed studies required to carry out the program.

Very sincerely yours,

M W Talbot
M. W. TALBOT
Acting Director

Enclosure

RS-CAL
RESEARCH PROGRAM
Problem Analyses
Fire

January 31, 1941

A FOREST FIRE PROTECTION PROBLEM ANALYSIS

FOR

CALIFORNIA

By

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California Forest and Range Experiment Station

Berkeley, California

ABSTRACT

California's forest fire situation, intensified by the size of the state, the value of its forest resources, its vast recreational use and travel, its long dry season and very inflammable, state-wide, watershed cover, is of such concern as to justify critical analysis from all possible angles. In the following pages it has been attempted to analyze the major problems in forest fire control confronting the several protection agencies of this state.

For this analysis some 370 questions were propounded, all important to California fire control yet none completely or satisfactorily answered. These 370 questions were combined into 77 generalized problems covering the fire protection fields of prevention, presuppression, suppression and effects. Each of these 77 problems was rated "high," "medium," or "low" as to its administrative importance by a group of qualified forest administrators. Of the 77 problems, 32 were judged of "high importance" rank. Of these 32 high importance problems, 8 were considered to be best solved by administrative studies, leaving 24 problems for solution by the research organization. These 24 high priority problems are considered as constituting the long-term research program of the Fire Division of the California Forest and Range Experiment Station. For the purposes of an immediate work program, these 24 problems were still further restricted to the problems, 13 in number, generally recognized as of outstanding importance. Of the 13 problems, 5 are in the fields of prevention and effects for which the staff at present is inadequate in personnel and facilities. The remaining 8 problems constitute the basis for the Station's program proposed for the immediate future. The current studies directed towards the solution of these 8 top priority problems are listed in the final table of this analysis.

In Section II of this analysis is given a brief resume of the topography, climate, cover types and forest resources of the state from the standpoint of fire control and also of the development and present status of the several fire protection agencies.

All problems, with their corollary questions, are presented with brief discussion in Section III. The evaluation of the importances and the procedure for selective high priority problems for the proposed research program are given in Sections IV and V.

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SECTION I

INTRODUCTION

The purpose of this analysis is twofold. It is one of a group of regional problem analyses expected to serve as a basis for a broad national program of forest fire protection research. It is also a basis for a detailed program of fire studies aimed at the orderly solution of current major protection problems in California.

The scope of the analysis is limited to the forest and watershed lands in California on which fire protection is an essential part of their successful management. The Forest Service, National Park Service, State Division of Forestry and five county organizations all participate in the protection of 43 million acres of these lands, or over two-fifths of the land area of California. The major protection problems are in general common to all agencies and have not been distinguished on the basis of jurisdiction in this analysis.

In addition approximately 20 million acres of rural agricultural and valley bottom lands are given some degree of fire protection by the State Division of Forestry and numerous county and fire district organizations. Problems peculiar to the protection of these non-forest lands are not considered in the analysis nor in the fire protection research program.

This problem analysis has been prepared by the staff of the Fire Protection Division of the California Forest and Range Experiment Station in cooperation with the administrative organizations of the Forest Service and State Division of Forestry. Descriptions of locally significant problems and opinions as to the relative importances of all problems were solicited by correspondence with many of the men throughout the state who possess particularly rich fire control backgrounds.

The problems were assigned values as to relative importance in conference with the Regional Forester and his staff. Assignments of different parts of the major problems to the Experiment Station for research attack were made in the same manner.

The helpful cooperation of various fire control men in the Region, and members of other divisions of the Experiment Station is gratefully acknowledged. The comments and suggestions of Duncan Dunning and Hubert Person, of this Station, were particularly helpful in the development of the Problem and Priority sections of the analysis.

THE IMPORTANCE OF FIRE PROTECTION IN CALIFORNIA

The fire control problems of California are increased in number and perplexity by the geographical extent of the state, the wide variations in topography, climate, and vegetation, the values of the forest resources, the numerous uses to which the protected areas are put, the different protection requirements imposed by the different land management purposes, and the several independent protection agencies which cover the state. In view of these important connections with forest fire control, the topography, climate, cover types, and resources of California will be briefly discussed in the following pages.

Natural Geography

Topography. California runs southeast by northwest from Mexico to Oregon, nearly 700 miles in length, and averages about 200 miles in width. It contains very nearly 100 million acres. About half the area is rugged, and for the most part, heavily forested mountainous country.

The state is characterized by a remarkable diversity in topographic features and for convenience of discussion may be divided into the seven different provinces shown in the accompanying figure.

(1) The Great Interior Central Valley, a level-floored depression more than 500 miles long and 20 to 50 miles wide. This valley is a vast plain of rich alluvial soil without rock outcropping or terrace, gradually rising from tide level near the center to an elevation of 420 feet at the southern end and 800 feet at the northern end. This great valley is enclosed on all sides by mountains; the Sierra Nevada on the east, the Coast Range on the west, the Klamath Mountains and volcanic plateau on the north, and the Tehachapi on the south where the Sierra Nevada and Coast Range meet. Along the sides are uplands and sloping plains or alluvial fans reaching to the foothills.

(2) The Sierra Nevada Mountains, the dominant physical feature of the state. This Sierra Nevada range is a great block of the earth's crust tilted toward the west. Along the eastern face are several valleys the largest of which is Owens Valley at an average elevation of 5,600 feet. The Sierras rise 8,400 feet higher with summits only 10 miles away in air line. From these 14,000 foot summits, the tilted block slopes gently for 150 miles toward the great interior valley which is only a few hundred feet above sea level. The eastern face is thus a short exceedingly bold escarpment; the western face is a long gentle slope.

(3) The Coast Range, forming the western rim of the interior valley. These mountains are entirely different in origin and structure from the Sierra Nevada, being rocks bowed in arches and severely fractured along critical fault lines. They consist of a chain or system of ranges running northwest and southeast, approximately parallel to each other with narrow valleys between. The hills are 2,000 - 3,000 feet high with characteristically rounded tops.

TOPOGRAPHIC REGIONS OF CALIFORNIA

1 INTERIOR VALLEY
2 SIERRA NEVADA MOUNTAINS
3 COAST RANGE
4 VOLCANIC PLATEAU
5 KLAMATH MOUNTAINS
6 COASTAL SOUTHERN CALIFORNIA
7 GREAT BASIN

(4) The Volcanic Plateau. This region is an extensive area in northeastern California broken by numerous ranges of mountains. It is geologically quite unlike the Sierra Nevada or Coast Range, being made up of lava rock with innumerable cinder cones and a line of volcanoes from Mt. Lassen reaching north of Mt. Shasta. The plains and valleys of this region have an elevation of 3,000 to 5,000 feet while some of the mountains, exclusive of the volcanic peaks, attain a height of 10,000 feet.

(5) The Klamath Mountain Region. This is the mountainous area in the northwestern part of the state, joining the Coast Range on the south and the Cascades in Oregon. Geographically these three mountain systems are not easily distinguished, but geologically the Klamaths are quite unlike the folded Coast Range and the volcanic Cascades, resembling more the granitic block structure of the Sierra Nevada. The Klamaths include the Siskiyou, Scott, Salmon and Trinity Mountains. The higher peaks rise from 7,000 to nearly 10,000 feet. Only three valleys of moderate size are found in this whole rugged region; the rest of the surface consists of steep slopes terminating in deep canyons.

(6) Coastal Southern California. Southern California south of the Tehachapi, is divided by a series of mountain ranges into two easily distinguished parts, the western one sloping to the ocean, the eastern one consisting for the most part of barren mountains and desert valleys. The latter is part of the Great Basin and is in sharp contrast to the coastal area. These mountain ranges are the Sierra Madre, San Gabriel, San Bernardino, and San Jacinto, and are continuous with the Peninsula Range in Lower California. In general they rise to 5,000 - 7,000 feet elevation with some peaks to 10,000 and 11,000 feet. The slopes are very steep and deeply creased, presenting a network of steep, narrow canyons and sharp ridges. The mountains very abruptly meet the valleys which stretch away to the sea.

(7) The Great Basin. This region includes that vast desert area of eastern California and Nevada east of the Sierra Nevada and Sierra Madre ranges. It is filled with a succession of barren mountain ridges and sandy desert valleys with no external drainage. It consists not of a single basin with a rim of enclosing mountains, but of a large number of smaller basins or valleys, some with an elevation of as much as 6,000 feet, others below the level of the sea. The Great Basin includes the eastern one-third of California, extends into the state of Nevada and beyond, with the Columbia and Colorado drainages forming the northern and southern boundaries. The region is arid, sparsely covered, and not seriously troubled by fire.

<u>Climate</u>. California has a coast line nearly 1,000 miles in length reaching through nearly ten degrees of latitude, but it is not this great sweep from north to south that gives the climatic factors in California their unusually wide range so much as the marked topographic contrasts to be found in the state. Within a few miles may be experienced all variations of climate from the sub-tropical to the arctic. The explanation lies in the climatic control by land and water surfaces, mountain barriers, prevailing winds, ocean currents and storm tracks.

The Pacific Ocean and the westerly winds give the narrow coastal fringe a true marine climate with a rather equable low temperature. The summers are cool and freezing weather in winter is infrequent. In this strip fogs abound both summer and winter, particularly in the north coastal area. These fogs follow the valleys and may be led through passes by the draft from the warm interior as far as 50 miles inland. In general, however, they are stopped by the Coast Range Mountains and rarely reach the interior valley. In the Coast Range Mountain districts, temperature is largely controlled by altitude and local topography. It is much more equable on the western than on the eastern slopes. Sunshine is abundant throughout the year. Precipitation is light and limited to the winter season. Light snows fall on the higher hills but measurable snowfall in the valleys is rare.

East of the Coast Range, the ocean influence disappears and most of the interior of the state has a continental or mountain climate. The interior valley has hot sunny summers with temperatures increasing both north and south of the gap opposite the Golden Gate through which streams cool marine air. Midday temperatures may reach 110° F. and extremes of 120° F. or more are on record. But, owing to radiation through the clear dry air, differences between day and night temperatures frequently amount to 40° or more. The period May to September is practically rainless. For most of the valley, the total annual precipitation is less than 15 inches, the average amount decreasing from north to south and practically all confined to the winter season. The winters are mild and often attended by a thin blanket of radiation fog. Measurable snow is rare. Frosts usually extend only from December through March.

In the Sierra Nevada, altitude is the important climatic control and the daily and seasonal temperature variations are large, somewhat more marked on the eastern than on the western side. The summer days are frequently hot but the nights are generally cool. At the high elevations freezing temperatures occur in midsummer and sub-zero temperatures are common in winter. On the western slope of the Sierra precipitation increases with altitude to about 6,500 feet above which the average precipitation decreases to the crest of the range. Precipitation on the eastern slope is considerably less than on the western side. The higher portions of the Sierra receive most of their precipitation in the form of snow, this being one of the regions of greatest snowfall in the United States. It often accumulates to depths of 30 to 40 feet but in the spring it gradually melts and even on the highest peaks disappears in June or July and does not reappear until October. Thunderstorms, accompanied by destructive lightning, occasionally occur in the summer but the midsummer precipitation is negligible.

Coastal Southern California shows a wide range in temperature because of the altitude extremes. The coastal fringe between Santa Barbara and San Diego has one of the mildest and most equable climates in the United States. In the mountains only a few miles from the sea low temperatures and heavy snows occur. The Los Angeles-San Bernardino Valley is not shut off from the ocean winds by mountain barriers so that the tempering marine air and fogs spread over the whole of this area. The daily and annual temperature amplitude increases with increased distance

from the coast. Precipitation in southern California is light, varying from 10 to 15 inches annually in the valleys to about 25 inches in the high mountains. More than 85 percent of the precipitation falls in the wet months, December to March. Excessively heavy rains frequently fall within short intervals of time. The heaviest precipitation intensity ever recorded in California occurred in these southern California mountains. From May through September practically no rain falls. Deep snow covers the higher peaks during the winter but none remains throughout the year. Sporadic thunderstorms originate over the Colorado desert, pass over the southern California mountains with little activity, and reach their maximum development in the mountains farther north. These summer storms are infrequent at the lower levels and near the coast.

Tornadoes and similar disturbances are almost unknown in California. The most harmful are the strong northern to eastern winds that occasionally blow for several days in the fall of the year. They are dry and hot and intensify the forest fire problem. In southern California this wind is locally known as the "Santa Ana".

The desert regions of southern California have very hot summers, with maxima averaging well above 100° F. in the low areas. The highest temperature ever recorded in the United States, 134°, occurred in Death Valley. The desert winters, however, are rather cool and freezing weather is usually reported each winter. These California deserts are the driest portions of the United States. Occasionally light rain or snow falls in the winter but practically none in the summer and the average annual precipitation is only 2 or 3 inches or less.

Thermal conditions in the volcanic plateau depend largely upon the elevation and sheltering influence of adjacent mountains and hills. Because of the general high elevation, the summer climate is cool and the winter is colder than in most other portions of California. The precipitation decreases as one goes east from the Lassen-Mount Shasta line from 45 to 60 inches down to 10 to 15 inches so that fully half of the region has a semiarid climate. About 90 percent of the precipitation falls between November and May, and about 10 percent from summer thunderstorms.

In the Klamath Mountain region the most noticeable climatic features along the coast are the moderate and equable temperatures, frequent and dense fogs, and strong northwest winds. Here freezing temperatures are uncommon, with rare and scant snowfall. Back from the coast, among the hills and valleys, the climate is entirely different with marked amplitude in temperature and humidity, but with slight wind movement. Temperatures depend largely on elevation and local topography. During the summer, afternoon temperatures may be above 100° F. but the nights are invariably cool. Winter frost and snowstorms are frequent in the interior.

Precipitation is of greater frequency and the monthly amounts are greater in this Klamath region than in any other part of California. The average annual fall for the area is about 40 inches; but departures from this average are wide. The precipitation is heavier in the western part but is more evenly distributed in the eastern. The well known wet and dry seasons of California are experienced even in this northwest section. In the winter season about 55 percent falls, but only 2 percent in the summer season from mid-June to mid-September.

Fire Weather. For the state as a whole the most important characteristic of the climate from the standpoint of forest fire protection is the hot, dry, summers with prolonged periods of 2 to 4 months with no precipitation of any consequence. During this period humidities and fuel moistures are low and all annual vegetation becomes dry, yellow, and inflammable. Low humidities with attendant low fuel moistures, plus extremes of slope and inflammability of cover have accounted for many uncontrollable fires. For short periods during practically every fire season supernormal winds occur, often accompanied by very low relative humidities and it is during such periods that many fires attain large proportions. Lightning is of important concern in California as in other western regions because of its characteristic tendency to set many fires within brief periods. Dry thunderstorms occur every year in the California mountains and produce on the average one thousand or more forest fires.

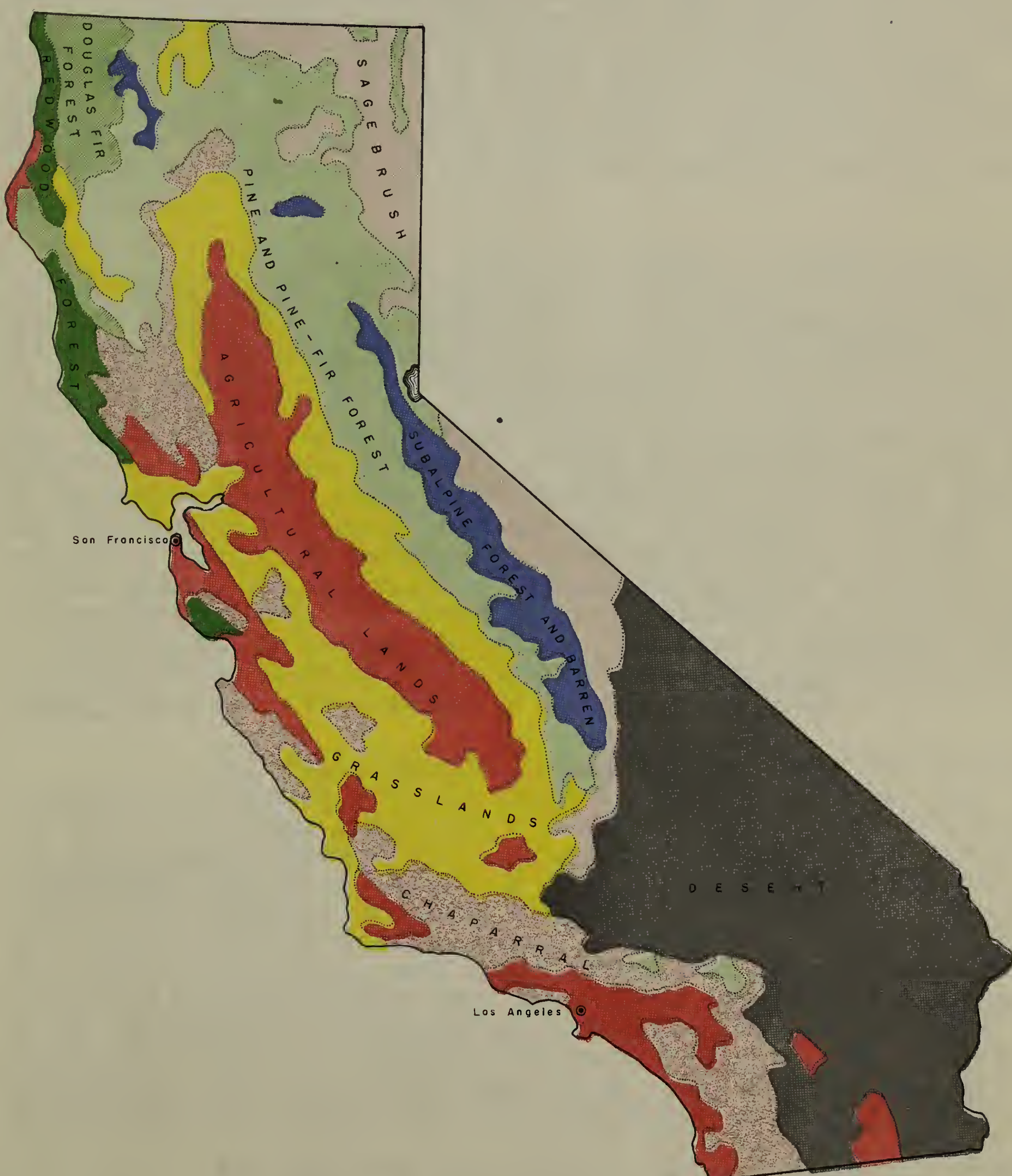
In an average year the fire season in the state as a whole extends from May 15 to October 15. These dates may be somewhat earlier or later depending upon current weather and such things as the snow pack and the stage of herbaceous growth. Particularly in the southern part of the state the closing date may be extended another two months, and occasional fires may occur almost any month in the year.

The forest fire weather varies widely in California from year to year. In some years prolonged adverse weather imposes a severe task upon the protection organizations. Entire seasons stand out in the experience of many fire control men when practically every fire seems to burn a little harder and a little faster and take more work to control. Even in an easy year there occur difficult days when fires are only controlled with the utmost effort. These fluctuations in fire intensity and fire load are of extreme importance in fire protection in this region.

Cover Types. Vegetation is of basic importance in fire control in view of its close relation to forest fire behavior and difficulty of fire line construction. Because of the latitudinal spread, broken topography, and climatic extremes in California, great variations exist in the vegetation cover types. However, for the purposes of fire control the many recognized forest types have been combined into the following groupings:

(1) Grassland. This type consists to a very large extent of annual grasses, such as the numerous species of *Bromus*, *Festuca*, and *Avena*; perennials, such as *Stipa*, *Poa*, and *Agropyron*; and associated herbaceous species. St. Johnswort (*Hypericum perforatum*), bracken fern (*Pteridium aquilinum*), wooly mulesears (*Wyethia mollis*), and poison oak (*Toxicodendron diversilobum*), are often conspicuous. Woodland oaks (*Quercus* spp.), Digger pines (*Pinus sabiniana*), juniper (*Juniperus* spp.), manzanita (*Arctostaphylos* spp.), and ceanothus (*Ceanothus* spp.) are frequently present but always typically open with the grass exposed. This grassland type is common on the Coast Range Mountains and the Sierra

DISTRIBUTION OF MAJOR VEGETATION TYPES IN CALIFORNIA.



Nevada foothills, and is characteristically found on slopes and other dry situations and occurs principally below the timber belt.

(2) Timberland brush. The vegetation in this type consists of those shrub species commonly associated with timber species, and occupying sites that are at least climatically suitable for growing timber crops. Chief among these species are greenleaf manzanita (*Arctostaphylos patula*), snowbush (*Ceanothus velutinus*), chinquapin (*Castanopsis sempervirens*), white thorn (*Ceanothus cordulatus*), deer brush (*Ceanothus integerrimus*), and blue myrtle (*Ceanothus thyrsiflorus*). Usually this timberland brush grows in very dense stands and offers great resistance to fireline construction. This brush is not a climax type and, with enough attention to fire control and reforestation, could probably be replaced at least on better sites by productive timber stands. Nevertheless, in a great many places in California, following destruction of the forest, it has captured the land and must now be recognized as a distinct and important cover type from the fire control standpoint.

(3) Chaparral. This type consists of shrub species, such as chamise (*Adenostoma fasciculatum*), manzanita, ceanothus, mountain mahogany (*Cercocarpus betuloides*), coffee berry (*Rhamnus californica*), Christmasberry (*Photinia salicifolia*), and scrub oaks (*Quercus* spp.). It is distinguished from the timberland brush in that it is probably not a temporary association but a permanent cover type natural to a large part of California where the soil, climate, and exposure make conditions unsuitable for coniferous forests or dense broadleaf stands. This type is characteristically rather dense with much dead wood. Litter under the pure chamise is usually light but under old stands of manzanita and oak may be four to six inches deep. This chaparral may, as in the central Sierra, be accompanied by oaks and Digger pine, but these trees are typically open and the shrubs greatly predominate and stand exposed to sun and sky. In southern California yuccas are a conspicuous part of the chaparral on south slopes, and buckwheats (*Eriogonium* spp.)and sages (*Salvia* spp.) are often abundant in the drier situations.

(4) Pine, pine-fir and Douglas-fir. Under this heading are included the following principal commercial conifers of California, — ponderosa pine (*Pinus ponderosa*), Jeffery pine (*P. jeffreyi*), sugar pine (*P. lambertiana*), incense-cedar (*Libocedrus decurrens*), and Douglas-fir (*Pseudotsuga taxifolia*). Stands of the above mentioned coniferous tree species are frequently associated with red and white fir, and sometimes with some broadleafed woodland trees. Virgin stands of this type are characteristically dense, well shaded with a deep layer of needle litter but little herbaceous understory. Bear clover (*Chamaebatia foliolosa*), a low, inflammable, and densely matted shrub common on north slopes in the central Sierra, is frequently important in fire control. Second-growth stands are more or less open, often with considerable young reproduction, and usually associated with herbs, shrubs, and brush.

(5) Fir. The pure fir type includes white fir (*Abies concolor*), red fir (*Abies magnifica*), and mixtures of the two. Sometimes they occur in association with other species, typically Douglas-fir

and Jeffrey and sugar pine. The type is defined as that coniferous type in which red and white firs comprise at least 80 percent of the stand of the trees. Dense, shaded, moist forests are characteristic of the pure fir type, with compact layers of humus and duff and much dead and down debris.

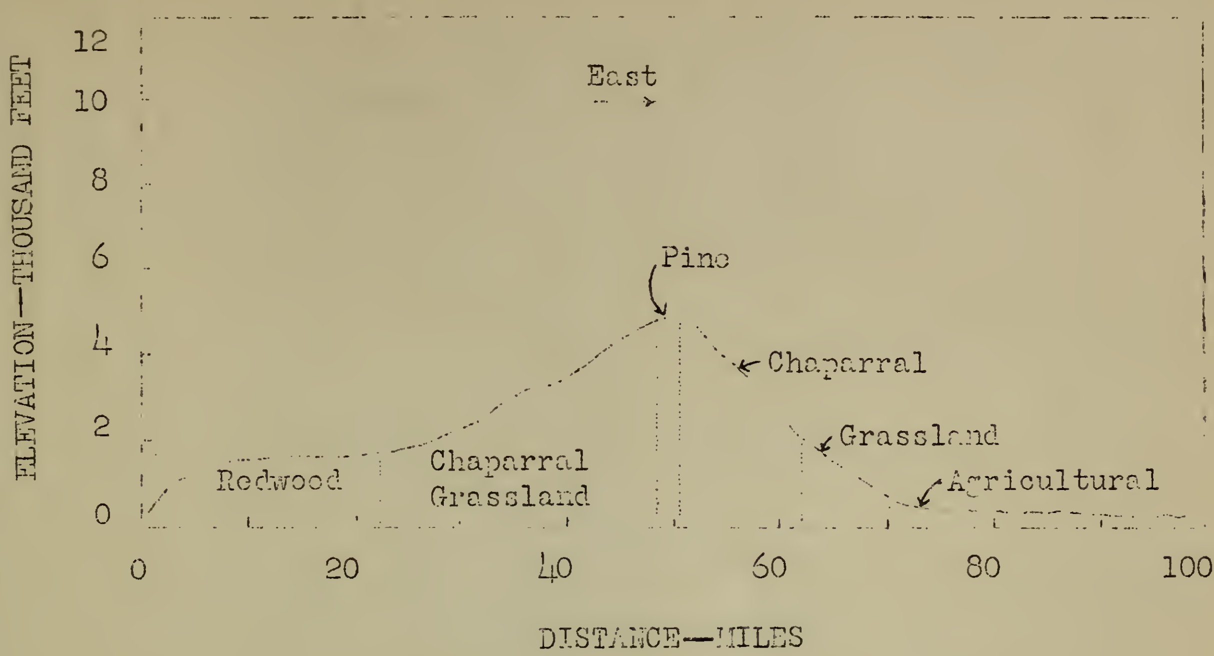
(6) Sub-alpine. Vegetational cover is defined as sub-alpine when 20 percent or more consists of certain tree species which, in California, are principally the following: Lodgepole pine (*Pinus contorta* var. *latifolia*), white pine (*P. monticola*), whitebark pine (*P. albacaulis*), foxtail pine (*P. balfouriana*), limber pine (*P. flexilis*), and mountain hemlock (*T. mertensiana*). These are often associated with herbs and shrubs, and with other conifers. These trees grow at higher elevations, usually on rocky terrane in shallow soil. This is usually a very open type, but rarely occurs in dense stands.

(7) Redwood. Designated as redwood is that type in which redwood (*Sequoia sempervirens*) occupies 20 percent or more of the stand of coniferous tree species. Commonly associated with the redwoods are Douglas-fir, lowland fir (*Abies grandis*), tanock (*Lithocarpus densiflora*), and Madrona (*Arbutus menziesii*), together with herbaceous plants, ferns, and shrubs, notably rhododendrons and other members of the heath family.

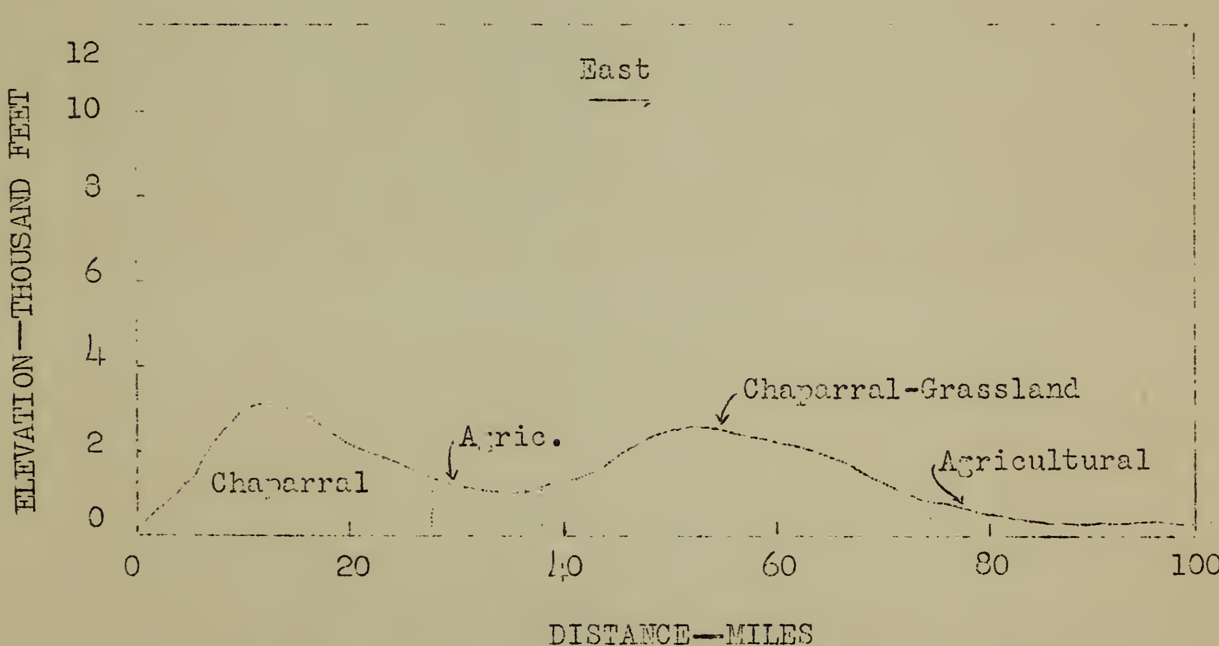
(8) Dense woodland and miscellaneous conifers. Three different types are grouped under this classification: (a) The stream bottom type consisting of dense to sparse stands of broadleaved trees such as sycamore (*Platanus racemosa*), alder (*Alnus* spp.), cottonwood (*Populus* spp.), willow (*Salix* spp.), maple (*Acer* spp.), and oaks; (b) Dense stands of tan oak, madrone, and other broadleaved woodland trees found in dry ravine bottoms, saddles, and neighboring slopes; (c) Miscellaneous conifers consisting of the following species, usually occurring in stringers or isolated clumps: Monterey pine (*P. radiata*), Coulter pine (*P. coulteri*), Torrey pine (*P. torreyana*), knob-cone pine (*P. tuberculata*), Bishop pine (*P. muricata*), and bristlecone fir (*Abies venusta*), big-cone spruce (*Pseudotsuga macrocarpa*), and various kinds of cypress (*Cupressus* spp.).

(9) Desert and semi-desert chaparral. This type is characterized by the dominance of such genera as creosote bush (*Larrea tridentata*), mesquite (*Prosopis* spp.), salt bush (*Atriplex* spp.), sage-brush (*Artemisia* spp.), sage (*Salvia* spp.), buckwheat (*Eriogonum* spp.), bitter brush (*Purshia tridentata*), and rabbit brush (*Chrysothamnus nauseosus*). This type may also be composed of species typical to the chaparral type, but differing from it in being characteristically open with the intervening ground space more or less lacking in vegetation. Pinyon pine (*P. monophylla*), and juniper, or Mojave yucca (*Yucca mohavensis*), will often be found as associated plants. This type is usually found in or bordering the desert or on slopes within the range of the desert climatic influence.

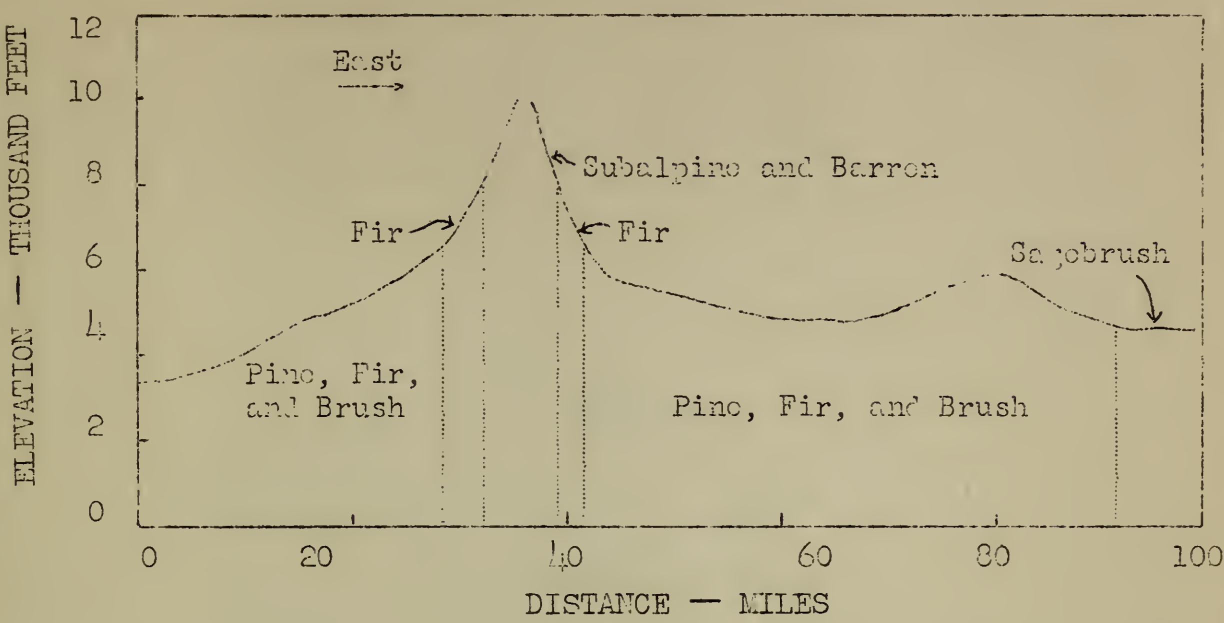
In a general way these major cover types succeed each other according to altitude. For instance in the Sierra, the succession is from the grass and chaparral in the foothills eastward through the commercial forests of ponderosa pine and mixed conifers on the western



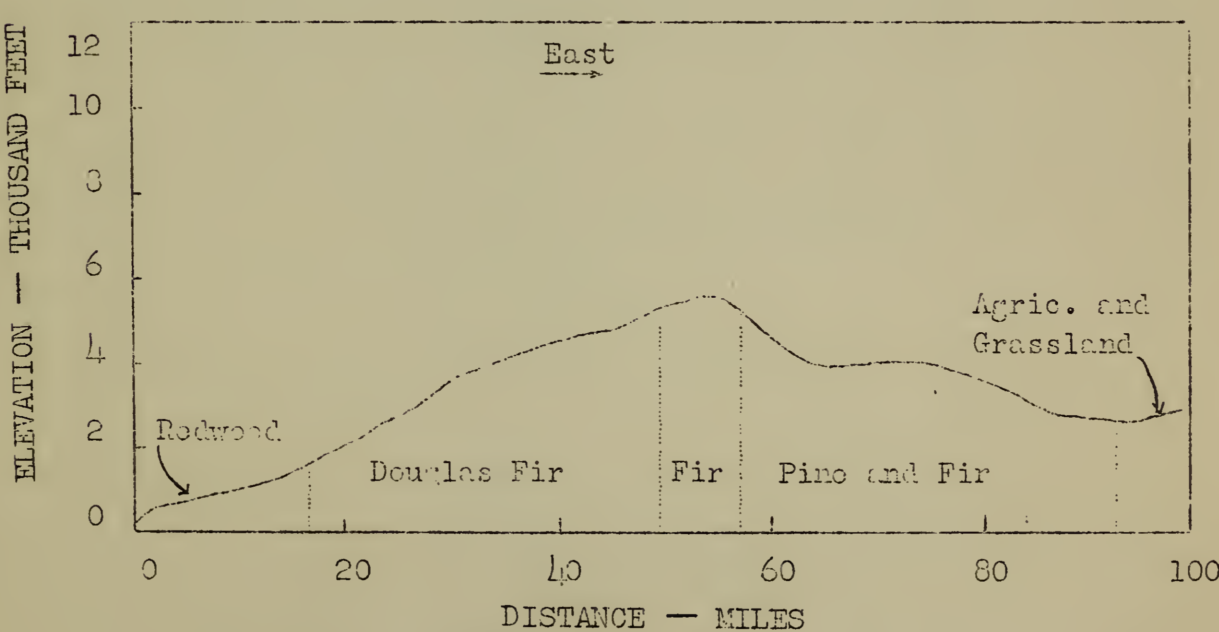
Typical cover-type distribution in the North Coast Region



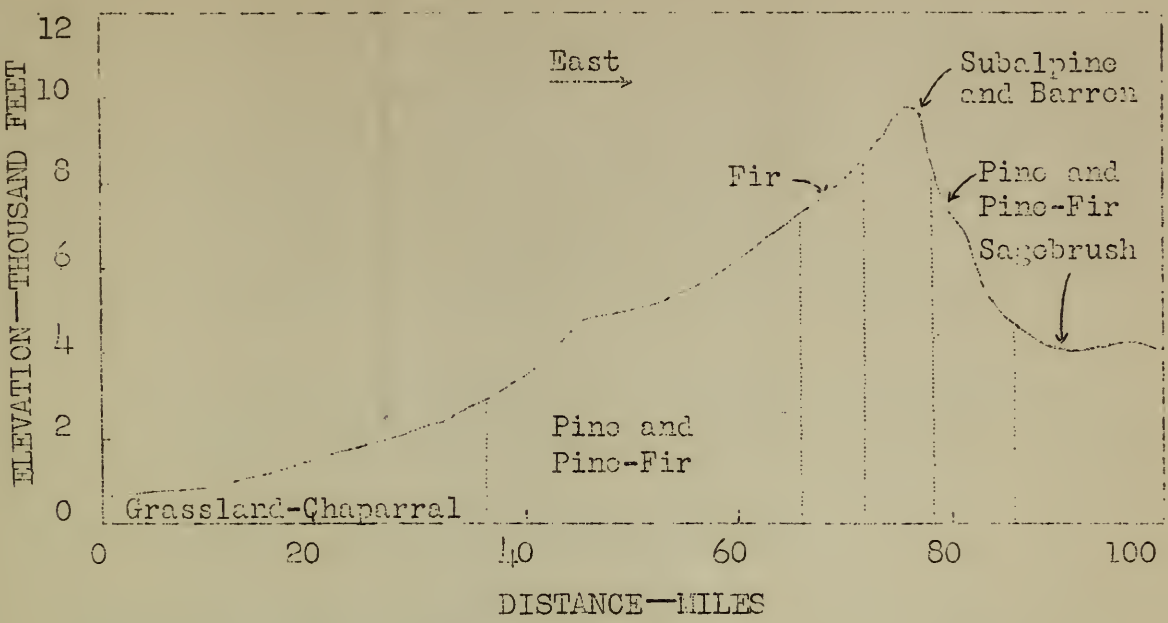
Typical cover-type distribution in the Central Coast Region



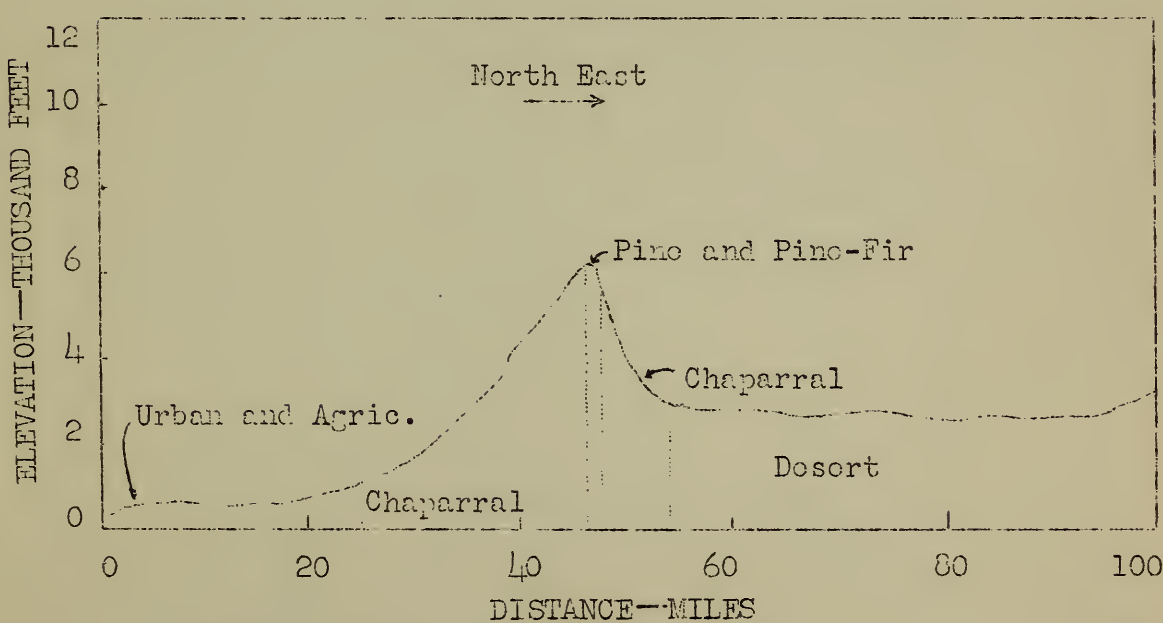
Typical cover-type distribution in the Volcanic Plateau Region



Typical cover-type distribution in the Klamath Mountain Region



Typical cover-type distribution in the Sierra Nevada Region



Typical cover-type distribution in the Southern California Region

slopes to the pure fir stands and scattered sub-alpine forests, thence across the summits descending on the east side through the pure fir and Jeffrey pine to the grassland and juniper and sage on the eastern plateau. An exception is the redwood type which is entirely confined to the northern California coast belt. Locally, the types are not clearly delimited because of variations in topography, soil, aspect and human activity, but usually are more or less intermingled. The normal zonation is further upset and in places obscured by the presence of brushfields resulting from fires, logging, or combinations of both.

In accompanying figures are shown the distribution of the more important common vegetation types over the state and across several of the topographic regions indicated in the topographic map of California.

Natural Resources, their Distribution and Use

General Land Use in California. The total land area of California has been roughly classified in the following major categories:

Valleys and lowlands	38 percent
Foothills (up to 2500 feet)	16 percent
Mountains (2500 - 5000 feet)	23.5 percent
Mountains (above 5000 feet)	22.5 percent
Total land area	99.6 million acres

The 99.6 million acres in California, according to data from the 1935 census, are divided into the following major classes of land use:

	Millions of acres	
Timberlands	19.7	
Woodland and chaparral	17.9	
Parks, primitive areas, etc.	6.1	
All forest land		43.7
Crop land in farms		8.7
Pasture land in farms	15.8	
Range land not in farms	6.0	
Total pasture and range land		21.8
Farm woodland		4.5
Urban, roads, etc.		4.6
State parks, etc.		0.7
The grazable desert		15.6
Total land area in California		99.6

The forest and watershed lands in California covering the foothill and mountain areas on which the federal, state, and county forestry departments are charged with protection may be classified as follows:

	Million acres
Forest land suitable or available for timber growing	13.6
Forest land suitable or available only for other purposes than timber growing (farm woodlands excluded)	30.1
Forest land important for watershed value	43.3
Forest land suitable for grazing	20.0
Total forest area	43.7

The principal uses of the California forests are for: (a) watershed management, (b) timber production, (c) livestock grazing, (d) wildlife, and (e) recreation.

Timber Resources and Lumber Operations. Of the 1,667 billion board feet of saw-timber in the United States, 213 or about 12.8 percent are in California. Practically all of this California saw-timber is softwood.

Of the 2,382 million cords of cordwood in the United States, 163 or about 6.8 percent are in California. Most of the California cordwood is softwood.

The commercial forest in California may be classified as to saw-timber and cordwood, and as to condition of the stand as follows:

	Thousand acres	Volume
Old growth, saw-timber, pine region	7,903	150 billion board feet
Old growth, saw-timber, redwood region	850	56 " " "
Second growth, saw-timber, pine region	1,107	6 " " "
Second growth, saw-timber, redwood region	50	1 " " "
Cordwood	278	163 million cords
Fair to satisfactory re-stocking	209	
Poor to non-restocking	3,358	
Total commercial forest	13,755	63 billion cubic feet

Ponderosa pine is widely distributed throughout California and is the most important saw-timber species. Douglas-fir, the great timber species of the Pacific Northwest is second, and redwood, although localized in the north coastal belt, is third in importance.

The principal forest products for California, 1937, were as follows:

	Number of establishments	Average number of wage earners	Value of products $ million
Lumber and timber products	177	17,977	56.6
Paper and allied products	105	5,313	43.0
Planing mill products	271	5,769	34.6
Furniture	293	7,311	30.2
Wooden boxes, except cigar boxes	68	1,560	9.2

Although California is the third state in lumber production, it is first in consumption. Accordingly the state is not self-supporting in this regard and imports actually more than it produces. The annual reported consumption per capita in the United States is 248 board feet, compared with 566 board feet in California. The consumption rate for California appears much the higher not only because of the abundance of bungalow type frame houses in the state, but because of the great quantities of wooden boxes, doors, sashes, and other mill products fabricated within the state for outside shipment.

In California private enterprise controls half the commercial forest land. About 60 percent of the 213 billion board feet of saw-timber is on these private lands as well as 60 percent of the current growth. Of the annual cut 88 percent comes from private lands, which are the most accessible and the best forest lands in the region. Practically all of the redwood timber and the most productive parts of the pine belt are in private ownership.

The direct investment in the forest industry is about 500 million dollars exclusive of dependent investments to service the industry. In California are 375 actively operating lumber mills and in 1939 the value of the lumber and timber products was 46 million dollars. This industry supported 175,000 people in 25 California counties and paid between 10 and 15 percent of the state's payroll. That this forest resource may not always provide such economic substance is indicated by the present 1 to 6 ratio of saw-timber growth to drain by fire, insects, and wood utilization.

Range Resources and Grazing. The forage produced by native grass and herbaceous plants under the trees and in openings in the forest is a major resource of forest lands. A large part of the forest lands of California is grazed by domestic livestock in the summer and autumn months of the year. The nutritious forage, cool climate, and shade of forest trees, all combine to facilitate growth of calves, lambs, beef, and wool.

Grazing statistics for the national forests of California are as follows:

Forest range area, millions of acres	10.7
Grazing capacity	
Thousands of cow-months	607.9
Thousands of sheep-months	1,033.3
Number of stock permittees on national forests	3,000
Deer population on national forests	260,000
Value of livestock run on forest ranges, millions of dollars	116.8

In addition to the above data for national forests, there are nearly 10 million acres in public domain, state control, and private ownership, of grass and woodland suitable for grazing in the foothills. For this area there is little information on grazing capacity or numbers of livestock.

Within or near almost every California forest range area, there are agricultural communities whose prosperity is mainly dependent upon livestock production. Most of the farms within the communities are small and far from markets. Without the aid of complementary forest land range, most of such farms could not long exist. These forest ranges, with their ability to produce high quality beef and mutton at a moderate cost for forage, are indispensable in offsetting the more expensive production and feeding of cultivated crops. Grazing may usually be harmonized satisfactorily with other major forest-land uses, and without forest ranges a large proportion of associated farm lands and the community life dependent upon this would never have developed so satisfactorily.

<u>Water Resource, and its use for Agriculture and Power</u>. The water furnished by the mountains in California is essential to the production of agricultural crops on hundreds of thousands of acres of rich land in the interior valleys because of the prolonged summer and autumn dry season. The mountains and foothill areas upon which the valleys depend as their source of water aggregate some 43.3 million acres. Effective precipitation falls on these areas during a period of only about 5 months in the winter and early spring. Below the 2500-foot contour it occurs as rain, between 2500 and 5000 feet as rain and snow, above 5000 feet in the Sierra Nevada and volcanic plateau mountains as a heavy winter snow pack. Run-off from snow melt remains plentiful into July and a rather well sustained flow continues through the summer from drainage of water that has seeped into the soil. This water flow is of utmost importance to power, irrigation, and domestic supply.

In California there are seven major drainage basins (1) San Joaquin River basin, (2) Sacramento River basin, (3) North Coast drainages from Oregon to San Francisco Bay, (4) Central Coast drainages from San Francisco Bay to Santa Barbara, (5) South Coast drainages from Santa Barbara to San Diego, and (6) Desert basin which takes in Owens Valley and certain eastside Sierra waters.

The San Joaquin River basin includes many westward drainages from the southern half of the Sierra Nevada and a narrow strip of the eastern part of the Coast Range. Approximately 2.5 million acres are now irrigated and a total of nearly 3.8 million acres is irrigable. The Hetch Hetchy project, costing $126,500,000 is designed to provide San Francisco and its environs (1940 population 739,000) with an adequate water supply from the Tuolumne drainage of the Sierra Nevada. A similar project draws water from the Mokelumne drainage for the East Bay Municipal Utility District (1940 population 610,000). Many valley towns and cities (1940 population 250,000) as well as large rural population (about 150,000) also depend upon the forested watersheds of this San Joaquin drainage for their water supplies. Water is in especial demand in the San Joaquin Valley and on the whole the water supply is inadequate. Near the southern end the water shortage is intense and the State Water Plan proposes to augment supplies in that part from those further north through construction of reservoirs and aqueducts in the Sierra Nevada foothills. Many of these dams and canals are now under construction.

The northern half of the interior valley, through which flows the Sacramento River, is broad, fertile, and irrigated by waters which drain from the surrounding mountains. The melting snow furnishes abundant run-off for irrigation and power in the spring and early summer. Rapid melting of this snow pack or heavy rains frequently cause damaging floods. On the volcanic plateau where the soil is partly decomposed lava and fairly level, moisture readily penetrates the soil and danger from run-off and erosion is slight. Elsewhere however, in this Sacramento River basin, a thick ground litter or understory of brush is important to regulate run-off and prevent erosion and floods. Shasta dam, now under construction at the upper end of Sacramento Valley, is designed to conserve water, prevent floods, regulate stream flow, and furnish water for power and irrigation. A total population, urban and rural, of about 300,000 depend entirely upon the water from the Sacramento River drainage.

The principal stream of the North Coast drainages is the Klamath River with its Scott, Salmon, and Trinity tributaries. These drain not only northwestern California, but also a small part of southern Oregon east of the Cascades. The demand for water in this Klamath region (1940 population 83,000) is relatively light and there is a considerable surplus over much of the area. Only in the upper Klamath River area is storage necessary to assure a sustained supply. The portion of this drainage south of the Klamath consists of a series of ridges and very fertile valleys kept well watered by the annual precipitation of 30 to 40 inches. The soil in this area is deep and very retentive of its moisture, and vineyards, orchards, hop fields, and truck gardens thrive without irrigation, supporting a population of about 157,000. This area, drained principally by the Mad and Russian Rivers, is much less subject to damage by floods than other parts of California.

Drainage in the Central Coast area from San Francisco to Santa Barbara consists of many little streams and creeks which are almost

invariably dry in the summer and autumn months. Although the precipitation may be fairly heavy, 15 to 30 inches annually, it falls in the wet season and practically none as snow. Demand for water for domestic and municipal use is heavy. It is from the Spring Valley development in the northern part of this basin that San Francisco obtains a large part of its water supply. Many communities in this drainage (1940 population 405,000) depend upon wells in which the water level is gradually dropping. The chaparral, grass, and forest cover of these drainages are extremely important for their watershed protection influence.

In the South Coast drainage area the water supply problem is one of the greatest in the United States. The great industrial and domestic demand of the 3,532,000 people in this area combined with the tremendous demand for irrigation water by the citrus fruit industry and other agricultural developments makes it necessary to conserve all possible water that falls upon the neighboring mountains. If importations by aqueducts be neglected, 90 percent of all water supplied in this area is derived from underground reservoirs underlying the valley floors on which the major part of the cities and towns and agriculture have been developed. These underground reservoirs or basins in turn get their supply by retaining a part of the wild and sudden floods of the region and a part of the rainfall which falls upon the overlying valley floors. They regulate by natural processes the surplus waters of the wet years for use in the dry years and have made the present economic development of the region possible. All plans for additional water supply propose further utilization of the underground reservoirs and control of the supplies in them, insofar as possible.

To this end many large water storage reservoirs, several thousand small flood control and debris storage basins, diversion dams, and water spreading grounds have been built at the base of the southern California mountains. On these projects over 200 million dollars were spent prior to 1940 in the Los Angeles and San Gabriel watershed district alone, and about as much more has been proposed to complete the general water conservation and flood control plan. In addition to these local water conservation projects, two great aqueducts each nearly 300 miles long have been constructed to import water from the Colorado River and from Owens Valley in the desert basin east of the Sierra Nevada Mountains. These great aqueducts, built at the enormous expense of approximately 550 million dollars, show the importance of the water supply for southern California.

The perpetuation of forests in California is of particularly vital concern to the agricultural industry. In late years it has become more and more generally realized that these two are complementary and to a considerable degree interdependent. Agriculture in every section of California depends on an adequate supply of irrigation water through the dry season — water which has its source in forested country. Moreover, forests protect the farms and orchards against damage from floods and erosion, furnish supplementary income to farmers, stabilize the population in submarginal areas, help to

lighten the farm tax burden, and, through the forest industries, offer part time employment and afford local markets for farm crops.

There are about three million acres in this state devoted to grains, grain hay, and cotton, the growth of which depends upon the local precipitation of the rainy season. But on nearly six million acres are raised crops entirely dependent on irrigation and ground water which has its source in the hills and mountains under forest fire protection. This irrigated land supports a rural population of nearly 700,000 people, represents an investment of nearly three billion dollars, produces nearly half the nation's fruit, including 62 percent of the total citrus, and an enormous variety and volume of nuts, melons, vegetables, and field crops, swelling the value of California's irrigated agricultural products to over 350 million dollars annually. Without forest cover flow of water would become irregular, larger and more costly storage reservoirs would be necessary, and it would be almost economically impossible to maintain the agricultural prosperity of this state.

There is great potential water power in the larger streams of the Sierra Nevada, volcanic and Klamath region. In hydroelectric development California ranks first in the Union and power is transported from the mountains over transmission lines to every part of the state. Of the 14.5 million horsepower developed from streamflow in the United States, about 2.3 million or 16 percent is in California. In addition, an estimated 228 million dollars is now being invested in the Central Valley power and water project. The Shasta dam unit of this project will have a capacity of 500,000 horsepower. In all cases the important power streams have their water sources in protective forest lands which favorably influence the water crop to such an extent that the protective value inherent in this forest influence must rank with other values of forest land.

Recreation in California. The great topographic extremes from volcanic mountains to glacier eroded valleys, the diversity and uniqueness of plant life from desert Joshua palms to the giant Sequoia, the wide distribution of wild life, the mildness of the ocean tempered mountainous climate — all tend to make the state of California one of the foremost in scenic and recreational values. The forested mountains in this state are within easy access by good highways even to the more distant populous centers on the coast and provide a playground for millions of people each year, both California residents and visitors from other states.

A prominent recreational use of the forests is by hunters and fishermen. The total number of deer hunters each year exceed 100,000 with an annual kill of about 30,000 deer. No data are available on numbers of fishermen and fish catch, but in the California mountains there are thousands of miles of good trout streams and hundreds of lakes which constitute favorable habitat for many valuable game fishes as well as the early life habitat for commercial anadromous species such as the salmon and shad. The economic and social values of fish and wildlife in forested areas must be considered in the complete program of forest land management and forest fire protection.

Recreation includes not only the use of the forests for hunting, fishing, etc., but their use for aesthetic, scientific and educational purposes as well. In the pine and redwood forests of California numerous summer camps have been established by various municipalities and social organizations, in addition to the many public camps maintained by the National and State Forest and Park Services. These camps are frequented by both children and adults who seek forest recreation for the preservation and stimulation of health, who appreciate the opportunity to study the forest and learn the mysteries of its development and functioning, who wish to escape from the mechanization and artificiality of civilization, and to enjoy that relaxation which is such an important attribute to outdoor living.

The recreational use of the California forests and parks is rapidly expanding. In 1929 the national forest and national park visitors amounted to 5.6 millions; in 1939 to 9.7 millions. There are several reasons for this rapid expansion; populations are increasing, working hours are becoming shorter, the standards of living are gradually rising, transportation, with the advent of the automobile and modern highway system, is becoming faster and easier, and the psychological necessity is increasing for an escape from the drabness of city life to the primitive of nature. Barring severe depletion of the natural beauty of the forests by over commercial exploitation and fire destruction, this expansion in recreational use is certain to continue.

Protection Requirements

The fire control objective in California is to provide the degree of protection needed to assure continuous maintenance of maximum public benefits from each forest resource at a justifiable cost. To state this objective in concrete and practicable terms, it is first essential that the resource management requirements be defined in precise terms with exact and measurable units.

At the present time there is no sound basis for combining into one figure the several resource management requirements for fire protection on the forest, watershed, and range lands of California. The reason for this is because adequate methods for evaluating fire damage to all forest values have not yet been devised. It is possible to measure fairly well fire losses to merchantable timber and to reproduction, but damages to the other resources and operations described, which normally occur in complex combinations, are not as readily ascertainable. The result is that total damages from fires cannot be evaluated to the extent necessary for assigning total protection requirements for any of the 43 million acres of California forest lands that are of value for more than the timber resource alone.

In lieu of the desirable total protection requirements, as yet undefined, the estimated requirements of the predominant resource has been accepted as a tentative basis on which to establish fire control objectives. Furthermore there is not general agreement as to the units in terms of which these objectives are to be expressed. However, since damage to a resource is generally roughly proportional to the area of the fire, the acreage burned has often been used for the fire control

objective. Such objectives are undoubtedly not ultimate, but they are workable and at present are recognized as the best available.

Burned area objectives have been established for the national forests but are still lacking or poorly defined for many other areas under fire protection. On the northern California national forests the present fire control objectives have been set at an average annual burned area of 0.2 percent for the commercial and potential timber types in the pine region, and at 0.5 percent for the lands valuable principally for watersheds and grazing. The objective on the timbered areas have been derived from analysis of the length of the timber rotation and the probable area that can be burned without disrupting sustained yield management. A similar method was employed in determining the fire control objective for the watershed and range lands. A growing recreational business within the mountainous areas imposes an additional requirement for intensified local protection over and above that required for management of the other resources. This objective is normally expressed in terms of maximum size of burn which can be allowed without seriously interfering with specific recreational uses. Determination of the watershed values of commercial forest, potential timbered, and range lands, and re-evaluation of the role of water in the statewide economy will tend toward more intensive protection on all of these lands.

Recognition of the critical role that forest cover plays in the production of water and in the control of floods and erosion in southern California has resulted in a demand for more intensive protection in that area. The need is indicated for the limitation of annual average burned area to 0.15 percent with the added objective limiting the size of individual fires to approximately 2000 acres. The necessity for intensive local protection on recreational areas prevails here as well as on the northern forests.

Development of Forest Fire Protection

Of the 43 million acres of forest and watershed lands in the State of California needing fire protection, 95.7 percent are at the present time being protected. The task requires the effort of several agencies which divide up the work as follows:

Area forest and watershed land protected	Acres
U.S. Forest Service	24,000,000
Federal land	17,000,000
Private land in and adjacent to national forests	6,900,000
National Park Service	1,110,000
State Division of Forestry	16,300,000
Individual Counties - (Los Angeles, Santa Barbara, Ventura, San Mateo, Marin)	1,500,000
Forest and watershed lands protected	42,900,000

Intensive and widespread protection did not exist until recent years. All of the agencies have passed through several stages of development both in physical facilities and methods of protection. A brief resume of the history of each will be given to afford a picture of past and possible future development.

U. S. Forest Service. Federal protection of forest and watershed lands in California began with the creation of forest reserves in the early 1890's. While the men assigned to administer the reserves were few they did what was within their power to protect them from fire. Often this consisted of gathering together a few helpers and following the fire, cutting it off here and there, until fall rains finally put it out. Mutual water companies, in some sections, were cooperators in these early efforts at fire control.

When the Forest Service took over administration of the national forests in 1905, the new organization soon added to the progress that had been made. By 1914, there were about 150 rangers and 500 guards employed at the peak of the fire season. In that year the fire protection objectives of the Service were stated to be an average of 10 acres per fire in all timber types and an average of 100 acres per fire in all open types, including brush and grass. At that time the average number of fires per year was 798. The average annual area burned for the decade 1910-1919 inclusive was 176,796 acres. In the latter part of the decade, changing fire control practices resulting from application of the economic theory of protection, accounted for much of the area burned.

During the next decade, despite improvement of fire fighting methods and equipment and a return toward more intensive protection, several years of extremely difficult fire weather raised the average annual burn to 220,429 acres. Toward the later end of this period significant fire control developments began to open up new possibilities of effective action. The suppression crew started to replace one or two man attack in certain areas. The first Forest Service tank trucks were built and the movable-blade bulldozer was developed. Near the middle of the decade the objectives of fire control were restated as an average annual burn of 0.2 percent in commercial and potential timber types and 0.5 percent in nontimbered types where the principal values were for watershed protection and grazing.

In the decade 1930-1939, greater strides were made in all phases of protection activity and the average annual burn reduced to 91,062 acres. During this period one of the most outstanding developments was the establishment of the Civilian Conservation Corps in 1933 which not only contributed greatly to the expansion of physical facilities such as roads, trails, and firebreaks, but also provided a reservoir of trained men for fire suppression. At the onset there were 128 CCC camps on the national forests, this number dwindling to 53 by 1935 and to 34 by 1940. Among other advances the techniques of detection and transportation planning were developed and applied intensively. The use of heavy equipment, such as tankers, and bulldozers in fire suppression, expanded rapidly. Objectives were modified by the adoption of a service wide suppression policy of

control within the first work period. Emphasis on the value of vegetation in flood control in southern California is now pointing towards the necessity of an objective stated as the maximum permissible size of a single fire.

The present fire organization on the national forests consists of the regular supervisors' staffs — 96 rangers and 14 assistant rangers plus a seasonal guard force of over 700 men, including 353 fire lookouts. The men in the 34 active CCC camps are also organized into suppression crews. These forces are aided in their work by 21,000 miles of roads and truck trails, 20,000 miles of horse and foot trails, and 3500 miles of firebreaks.

The direct costs of fire control on the national forests averages annually $560,000. Costs of suppression vary between $97,000 and $858,000 and averaged $382,000 annually for the past 10 years.

National Park Service. While the numbers of visitors on the 1,110,000 acres of national parks are large the number of fires is relatively small — less than 150 per year — and the burned acreage is normally negligible. The intensive development and manning of the parks for recreational purposes has been accompanied by a comparatively high level of protection. With the exception of some strips bordering the foothills the parks contain, in general, the less inflammable types of cover.

State Division of Forestry. Real progress in state forest fire protection began in 1919. Until that time the main reliance had been on voluntary firewardens with only moderate success. In this year, however, the State Forester was authorized to enter into protection agreements with federal, county, and city governments and with individuals. A biennial appropriation of $25,000 was secured for firefighting and with $3,500 made available for protection under the Weeks Law, four state rangers were employed.

Subsequent development of state protection was rapid. By 1921 there were 21 rangers and one lookout; the state was appropriating $37,500; $22,750 was obtained under the Weeks Law; and county and private cooperation contributed $17,000. The Compulsory Patrol Law of 1923 was the next big step forward. This act required protection of private timberland by residence or the payment of fees not to exceed 3 cents per acre for protection.

Passage of the Clarke-McNary Law in 1924 gave further impetus to state fire protection. By 1930 the resources and facilities of the Division of Forestry, as well as its field of operation, had been greatly expanded. Over $612,000 was available for the work of the Division which now had the responsibility of protecting 30,000,000 acres. Regular field men numbered 178.

In recent years the State's protection work has been intensified even further. The extent of this trend by 1938 may be partly gauged by the number of regular personnel employed. Those totaled 216 and included 48 rangers, 80 assistant rangers, and 47 lookout observers. In addition, 526 part-time men were employed in organized suppression crews at the peak of the fire season. The Division operated 330 pieces of automotive equipment, including some 60 pumper trucks belonging to the state and 29 county-owned pumper units. Seven CCC camps were under the direction of the State Forester furnishing manpower for fire fighting as well as for the construction of motorways, telephone lines and other fire protection improvements. Total expenditures of the Division in 1938 amounted to $731,698.

County Organizations. Most counties obtain their protection through agreement and cooperation with the State Division of Forestry. However, the counties of Los Angeles, Ventura and Santa Barbara in southern California, and San Mateo and the Tamalpais district in central California operate their own protection systems. These agencies protect 1,511,725 acres of forest and watershed lands. The City of Los Angeles, acting independently, also protects some areas of watershed cover. All are concerned with structural, grass and grain fires as well as watershed fires. Los Angeles County has by far the largest organization with an annual expenditure of approximately $300,000 for protection and about $600,000 invested in equipment and facilities.

Recent Accomplishment in Fire Control. The overall picture of fire control results of recent years is presented in the accompanying table. It will be noted that the number of fires varies from 2,377 in 1930 to 5,504 in 1939. Some of this variation is due to varying numbers of lightning fires in different years but the general trend in occurrence of man-caused fires is upward. This does not necessarily indicate ineffectiveness of prevention work because public use of forested areas has increased much more proportionally than the number of fires. It does indicate the need for better methods and more effort.

It will also be apparent from the area burned figures that the suppression problem is far from being solved. This is somewhat more true of state and private areas than of federal lands where the average annual burn has been 0.38 percent since 1930. In general it may be said that the present organizations are approaching adequacy for the less difficult years but are still unable to deal successfully with critical seasons.

The data on reported damage from fires are presented although it is well recognized that these figures are only nominal; that resources destroyed, except for timber, are evaluated on an arbitrary basis, and the real damage may be several hundred percent above the reported amounts.

Forest fires in California: Number of fires, area burned, and damage for state and private lands, and federal lands, by years, for years 1926 - 1939, inclusive.1/

Year	All California			State and Private			Federal		
	Number of fires	Area burned	Damage	Number of fires	Area burned	Damage	Number of fires	Area burned	Damage
	Number	Acres	Dollars	Number	Acres	Dollars	Number	Acres	Dollars
1939	5504	621,080	1,561,410	3697	475,420	942,920	1807	145,660	618,490
1938	3715	234,410	1,760,020	2605	171,810	1,591,120	1110	62,600	168,900
1937	2992	62,260	173,620	2093	48,140	130,590	899	14,120	43,030
1936	4203	796,900	2,926,760	3197	734,820	2,478,770	1006	62,080	447,990
1935	3560	178,620	729,740	2601	162,590	670,850	959	16,030	58,890
1934	4015	430,120	1,709,230	2852	365,410	1,028,620	1161	64,710	680,610
1933	2816	212,290	506,520	2137	141,190	398,360	679	71,100	108,160
1932	3499	502,580	793,860	2455	210,420	349,810	1044	292,160	444,050
1931	3626	1,006,530	2,590,700	2838	899,410	1,777,800	788	107,120	812,900
1930	2377	221,370	500,320						
1929	2858	804,430	2,279,850						
1928	2762	1,170,020	2,453,970						
1927	3367	729,410	928,810						
1926	3056	1,145,430	1,465,770						

1/ Source: "Forest fire statistics" published by Division of State Cooperation, U.S.Forest Serv.,Washington D.C

Research. Fire research has been closely allied with forest protection in California through most of the past 30 years. As early as 1909 there was considerable interest in the study of fire damage as it related to the then prevalent practice of light burning forest and range lands. It was not until about 1915, however, that intensive study of damage from fire was undertaken. By 1920 this work had demonstrated many of the detrimental effects of fire and had pointed out the important role of damage in fixing fire control objectives. This marked the end of that period during which the fire control objective had swung from that of minimum damage through that of minimum cost of protection plus damage, and finally back toward more intensive protection. S. B. Show, E. N. Munns, and Duncan Dunning were among the outstanding contributors to these early damage studies.

It was during the middle of this same 1910-1920 decade that the first active interest in the relationship of fire behavior to weather and fuel variations became evident. Both ignition and rates of spread were subjected to study and experimentation by Show during this period. Wind, humidity, and fuel moisture were demonstrated to be important controlling fire behavior variables.

Early in the 1920's there was a new approach to California fire problems. Show and Kotok began the task of unravelling the vast store of information recorded in some 10,000 individual fire reports accumulated during the previous decade. The methods of analytical treatment they developed and the information derived from the analyses have been of tremendous importance in furthering fire control practice throughout the Region.

All fire research activities took the form of administrative studies until the Experiment Station was established in 1926. It was not until 1930 that formal fire research studies were undertaken as part of the Station program.

Starting with a staff of 3 men and an annual expenditure of $11,000 at the time of its organization, the Fire Division was expanded rapidly with advent of the emergency program of the middle 1930's. During that time a staff nearly double that of the present and acquisition of much needed equipment and facilities were made possible. This assistance has now been withdrawn and operations are again within the scope of regular allotments approximating $27,000 per year. Five regular employees are assigned to the Division.

The major accomplishments of this first 10 years of organized fire research have been confined to the study fields of Control and Behavior.

Improved lookout detection planning methods have been developed by the Station and much information has been added to the knowledge of factors influencing forest fire discovery time.

A cooperative planning project with the Region developed for all California national forests complete plans for lookout detection and for communication facilities. These activities were followed by a similar project for transportation and manpower placement networks. The Experiment Station was also active in the recently completed replanning project.

Through all the years of planning and replanning the continued need for information on changing trends in fire business and in control accomplishments as well as for information on the probable effectiveness of proposed measures has been met through analysis of individual fire report data of the past 25 years.

Research has provided the information on rate of spread and on the variables concerned which form the basis for the present fire danger rating system. The large number of statistical analyses necessary in development of the system have been made by the Experiment Station.

Methods for measuring and estimating variables influencing rate of spread have been improved, preliminary determinations of the effects of wind, moisture, and slope on rate of spread have been made, and there has been much progress toward determination of the influence of fuel variations on rate of spread.

Improved methods for killing stumps and for sterilizing soil against annual grasses and weeds by the application of appropriate chemicals have been developed. The methods have been put into general application on roads and firebreaks on the national forests and on railroad and power line right-of-ways.

SECTION III

PROBLEMS IN FIRE PROTECTION

In the following section of this analysis are listed 77 general fire protection problems which are of administrative importance in the fire control job in California. The problems, in total, are intended to cover all phases of fire protection in order to gain a complete picture of the whole field, the relationship of its parts, and a definite realization of the size of the research task. Although many of the problems appear at first glance to be matters of administrative decision, further consideration emphasizes the need for research to supply basic information upon which sound judgment can be made. The statements of these problems have purposely been worded concisely, but inasmuch as the function of research is not only to determine relationships, secure data, and develop methods but also to suggest practical uses for and means of applying such findings, it is tacitly understood that the solution of each problem involves, in addition to the preliminary fact-finding investigation, the process of gaining practical application for all results so derived.

Paralleling these problems which are arranged under the usual activities of prevention, presuppression, suppression, effects, and economics, is a brief discussion intended to clarify their content. This portion has intentionally been made brief since it will generally be apparent to the reader what value the indicated knowledge would have in fire control.

Under each problem are listed one or more questions intended to indicate specific needs and to stimulate thought leading to the realization of other gaps in existing knowledge. It should not be assumed that these questions cover everything in fire control that might be asked by the forest administrator. Opposite each question is indicated briefly the status of knowledge on that particular question. It may be noted that currently accepted answers to the listed questions are very often based on individual experience, personal judgment, poorly refined methods, or incomplete records, and are rarely completely satisfactory. The presentation brings out clearly the great lack of factual information and the serious need for further investigation on almost all phases of fire protection.

PREVENTION

Active fire prevention work has been proved by long experience to be essential to any satisfactory approach to the attainment of fire control objectives in California. The annual burned area from man-caused fires can be reduced by prevention means. The reduction in burned area follows the law of diminishing returns, however, and this, together with the undesirability of great curtailment of human use of the areas through extreme preventive restrictions, limits the extent to which prevention effort may be justified.

In the administration of a forest, that balance must be maintained between expenditures for prevention, presuppression, and suppression which will result in the lowest total cost of protection. The major prevention problems involved in maintaining this balance are determination of the relative needs for allotments, and the methods and practices by which application of these allotments will result in the greatest reduction of fire load with the least curtailment of desired use of the resource protected.

Problem 1.

THE OBJECTIVES AND POLICIES OF FIRE PREVENTION WORK

The objectives of fire prevention work must be consistent with the objectives of fire control. They must recognize the limitations imposed upon possible accomplishments by limited appropriations and by limited knowledge of human behavior. And finally they must be consistent with the requirements of the actual or planned uses of the areas under protection.

Fire prevention must be directed towards human beings, and therefore fire prevention policies must take into consideration human attitudes. Various attitudes may be taken by the public towards fire control, such as: (1) approval of use of fire in the woods and antagonism to any fire prevention program; (2) passive lack of interest in the effort to halt the setting of fires; (3) sympathy towards the fight against fire but condonement of fire setting as an unavoidable evil to be expected. Attitudes of this sort must be recognized and dealt with.

In fire prevention work with the public there may be many important objectives, as, for example: to teach the condition under which ignition is likely and fire is dangerous, to arouse public consciousness of fire starting as a violation of law or regulation, to build up in community leaders an intelligent understanding of the detrimental effects of fire, to teach individuals ways and means of preventing and suppressing fires, to stimulate a sympathic public attitude toward fire control endeavors, or to develop an appreciation of the value of a forest as a public asset and heritage. The form of the objective could quite properly vary with the public attitude encountered.

The organizational means of best fulfilling the objectives may be a matter of policy, empirically or experimentally formulated, through which such things would be determined as the need for and structure of a general fire prevention organization, the extent of standardization of prevention activities between units, and the ways and means of financing and of distributing allotments.

QUESTIONS	STATUS
a. What should be the objectives of fire prevention work?	To date, not well defined. Known in what direction prevention is headed but not how far to go.
b. What policy could be followed to meet best the fire prevention objectives?	National policy for preventing forest fires is still in the making.
c. What public attitudes should be recognized in formulating fire prevention policies?	Requires special study.

PREVENTION - OBJECTIVES AND POLICIES

QUESTIONS	STATUS
d. What should be the fire prevention objectives with regard to different public attitudes to the fire problem?	National policy for preventing forest fires is still in the making. Requires special study.
e. What should be the objectives in fire control law enactment and enforcement?	Do
f. What should be the administrative policy towards a centralized permanent organization responsible for forest fire prevention and towards sustained fire prevention activity?	National policy for preventing forest fires is still in the making. Requires special study.
g. What should be the policy as to standardization of prevention methods by different protection agencies?	Do
h. What policies could be followed to insure equitable distribution of prevention expenditures among different protection agencies?	Do

Problem 2.

EFFECTIVENESS OF FIRE PREVENTION ACTIVITY AND OF INDIVIDUAL FIRE PREVENTION MEASURES

A yardstick is needed for measuring the effectiveness of prevention work. Only upon an accurate knowledge as to how much benefit is bought by any given expenditure of time, money, and energy in prevention work can be based the relative merits of various methods of prevention, the effectiveness towards particular classes of people, the relative importance of prevention in different areas, the need for further prevention effort, and the advantage of prevention over presuppression and suppression activities.

QUESTIONS	STATUS
a. How can the results of fire prevention activities be measured?	To the best of knowledge, no method of investigation has ever been devised. There is extreme need for this measure. Problem is similar to that of measuring the value of commercial advertising media. There is a possibility that some indications can be found through analysis of available data.
b. What is the relative importance of prevention work in different localities?	No established criteria. Methods are needed to secure equitable distribution of effort.
c. How can the extent of knowledge of fire laws and regulations be measured?	No established methods, but needed as an indication of additional educational needs.

Problem 3.

SUSCEPTIBILITY OF DIFFERENT FOREST FUELS TO IGNITION

What fuels are apt to be ignited is the first question that arises in any hazard reduction work. Although it is well known that fuels differ in ignitibility and qualitative differences can be recognized, no quantative classification on this basis has been developed. Effective and economical hazard reduction work depends on our ability to recognize those particular fuel combinations which have a controlling influence on the readiness with which fires start. A classification of fuels according to ignitibility by different firebrands would permit economical concentration of this phase of prevention effort where it is most needed.

QUESTION	STATUS
a. What is the relative ignitibility of different fuels by different firebrands?	Qualitative groupings are recognized. A few preliminary studies have been made but no quantitative classifications have been developed.

Problem 4.

SPECIFICATIONS AND METHODS FOR FIREPROOFING LOGGING SLASH, RIGHT-OF-WAYS, CAMPGROUNDS AND OTHER FOREST AREAS EXPOSED TO DIFFERENT KINDS OF USE

Once the contribution of various fuels to ignitibility is known there arise practical problems on the methods of disposing of particular fuels or in other ways modifying their condition to reduce the probabilities of ignition. The more important of these problems deal with methods of treating logging slash, cleaning up camps and roadsides, and fireproofing improvements and construction operations.

Another group of problems is concerned with prevention of fires through promulgation of minimum specifications of methods and width of treatment of inflammable material necessary to different conditions of use.

QUESTIONS	STATUS
a. How can slash areas be fireproofed most advantageously?	Considerable research has been done and various methods are commonly practiced, but little information is available on relative effectiveness and economies under varying conditions.
b. How can dead and down debris be most effectively treated?	Do
c. How can inflammable herbaceous vegetation be effectively treated?	Various mechanical methods for removing vegetation are in general use. There is much experimental information available on the use of chemicals and chemical treatments are coming into limited use.
d. What materials should be removed in fireproofing roadsides, campgrounds, right-of-ways, etc?	Methods of performing such jobs have been developed empirically by different agencies. There is not sufficient information available on which to base minimum specifications for clearing. The possibilities of economy and greater effectiveness with less work have not been thoroughly investigated.
e. What are the minimum specification requirements for adequate fireproofing of industrial and construction operations in forest areas?	Do

f. What are the minimum specification requirements for fireproofing forest residences and building sites?

Methods of performing such jobs have been developed empirically by different agencies. There is not sufficient information available on which to base minimum specifications for clearing. The possibilities of economy and greater effectiveness with less work have not been thoroughly investigated.

g. Under what right-of-way conditions do railroad fires start?

Although the numbers of railroad fires are generally held at low levels, further reduction in frequency appears possible through more exact knowledge of the conditions attending fire ignition.

Problem 5.

REDUCTION OF FOREST IGNITIBILITY, RATE OF FIRE SPREAD, AND DIFFICULTY OF CONTROL THROUGH MODIFICATION OF SILVICULTURAL, LOGGING, AND GRAZING PRACTICES

Harvesting of timber is normally accompanied by at least a temporary increase in subsequent inflammability. The extent of this increase depends upon conditions within the original stand, the silvicultural treatment, and methods of logging employed. The increase in inflammability and difficulty of control is very great in redwood stands where the problem assumes added importance because of the extraordinary quantity of slash left after logging. The management problem is to devise ways and means of reducing this subsequent danger to a minimum as, for example, through providing overgrazed strips, strips of timber left in cut-over areas, or strips of hardwoods planted through coniferous forests. Under intensive management, physical prevention measures within stands during the period between harvests, may also be justified.

QUESTIONS	STATUS
a. What is the effect of silvicultural treatments on inflammability and difficulty of control?	Theoretical considerations form the basis of most current objectives and practices. Little quantative information is available. In California there is little practice of what is known.
b. How can logging be carried out to minimize subsequent forest inflammability?	Do
c. How can forests be treated to reduce susceptibility to lightning fires?	No quantitative information available.

Problem 6.

EQUIPMENT TO MEET HAZARD REDUCTION NEEDS

In slash disposal, right-of-way clearing, snag disposal, soil sterilization, removal of inflammable vegetation, and elsewhere in fire prevention work, mechanical equipment is often employed or could be employed if suitable types of equipment were available. A problem in management is to adapt such equipment specially to the prevention work needs.

QUESTION	STATUS
a. What are hazard reduction equipment needs and how well are they met?	The equipment in general current use has largely been adapted with few changes from other fields. A few items of special apparatus are available.

Problem 7.

THE RELATIVE PROBABILITY OF IGNITION OF FOREST FUELS BY DIFFERENT FIREGRANDS

Practically all firebrands, other than lightning, owe their existence to human activity subject to control through prevention effort. To exercise such control intelligently, however, it is necessary to know not only what are firebrands, but also the relative importance of the various firebrands in starting fires, the characteristics of each firebrand that make it dangerous, and the environmental conditions under which ignition is probable.

QUESTIONS	STATUS
a. What is the certainty with which various firebrands start fires? b. What are the physical characteristics of firebrands that influence their fire starting ability? c. How does ignition probability vary with size, kind and temperature of carbon sparks?	Several people have worked on various phases of ignition particularly on size and temperature of carbon sparks and the limits of fuel moisture at which carbon sparks start fires, but little or no work has been done on other firebrands and the necessary information on the whole field of firebrands and ignition is still very meager.
d. Do motor vehicles with serviceable standard equipment cause fires?	Do

Problem 8.

REDUCTION OF PROBABILITY OF IGNITION OF FOREST FUELS THROUGH ELIMINATION, MODIFICATION, OR CONTROL OF FIREBRANDS

Knowledge of the potency of different firebrands, fundamental to the phenomenon of ignition, would find application in properly focusing prevention work on the more important causes and in pointing to ways and means of rendering firebrands associated with these causes less hazardous, and of operating industrial equipment with less danger of causing fire.

QUESTIONS	STATUS
a. How can firebrands be controlled, eliminated, or made less hazardous?	Although considerable progress has been made, especially in the field of spark arresters, definite information is needed on ways of controlling other firebrands and methods of designing and operating industrial equipment to minimize the fire starting probabilities.
b. How can the efficiency of spark arresters be measured and improved?	
c. Under what operating conditions do railroad and other industrial and utility fires start?	
d. How can industrial and utility equipment be operated to result in minimum numbers of fires?	Do

Problem 9.

THE RISK ACCOMPANYING DIFFERENT FIRE CAUSING AGENCIES

The forest administrator is usually in a position to measure fairly exactly the amount of use being given an area at any time. What is needed is some means of translating such a measurement into terms of fire expectancy and fire control needs.

QUESTIONS	STATUS
a. How many fires may be expected from a given number of hunters, fishermen, campers, special use permittees, automobilists, and other fire causing users?	Definite relations have not been worked out, but some data probably exist which might be utilized if gathered together.
b. How can risk be used in a fire prevention index?	Do

Problem 10.

THE PREVENTION MEASURES BEST SUITED TO COUNTERACTING THE FIRE STARTING HABITS OF FOREST USERS

Not all classes of people are equally responsible for starting forest fires and therefore prevention work should be aimed at specific groups. For this purpose forest users could be classed for example as: adults and children; residents and visitors; rural and urban dwellers; high, medium and low income levels; occupational; or according to the manner of use — special use permittees, hunters and fishermen, picnickers and hikers, transients, vagrants, miners, industrial workers, etc.

The educational approach to each group of people should not be the same inasmuch as these groups differ as to motives, methods, places, and times for starting fires. Itinerants would not be reached through the same channels as professional men; children would not be susceptible to the same educational programs as adults. It may be that certain groups, like tourists, start fires mainly because of unfamiliarity with fire prevention ordinances. Most people lack an adequate understanding of the conditions under which fires are apt to start and an appreciation of the great danger from forest fires. There are many channels through which prevention effort can be directed in order to develop this understanding and appreciation of fire danger; lectures, editorials, news items, radio programs, moving pictures, exhibits, signs and posters, law enforcement, personal contacts, and many others. Each would impress its sermon best on particular groups, and economy and efficiency in prevention work would require adaptation of the method to the subject.

Carelessness and indifference may be so ingrained in human nature as to impose a limit in educational fire prevention work beyond which further effort would be uneconomical. It is obviously important to have this point clearly established.

It has been suggested that in order to reduce fires still further in number, potential forest users be classified as to their safety knowledge and safety habits. Permits to use high hazard areas would then be issued only to the better risks. The difficulties and costs of making such a classification must of course be considered.

One of the best of protection measures is the setting up of good examples. In this connection, free and legal burning of private land, if conducive to laxity on protected areas, would not be a good example to the proponents of light or uncontrolled burning, or to the general public towards whom prevention effort is directed.

In addition to educational and psychological methods of fire prevention, physical methods are available for reducing the number of fires. A few obvious examples are: clearing roadsides of inflammable vegetation, improving campgrounds, facilitating disposal of cigarettes and matches, installation of more frequent smoking and comfort stations, closer inspection of permittees, and rendering firebrands less dangerous. An intensive consideration of this problem would surely reveal many novel and valuable physical prevention methods warranting immediate exploitation.

PREVENTION - RISK

QUESTIONS	STATUS
a. To what extent do various classes of people start fires?	Beginning with the 1940 fire reports, data to answer this question are being taken. Past fire reports are not entirely satisfactory although much information can be obtained from them. Analysis of the data that are available is badly needed.
b. Why, how, where, and when do different classes of people start fires?	Over many years an attempt has been made to record in fire reports the circumstances under which man-caused fires started. However, in most cases the information is too general to answer specific questions regarding different classes of people.
c. How extensive is knowledge of fire prevention ordinances?	No information is available as to how familiar people are with fire prevention ordinances.
d. What are the best methods of educating the various classes of people in fire prevention?	No conclusive information is available as to the best educational methods of reaching the different classes.
e. What is the relative effectiveness of different kinds of subject matter in fire prevention education?	Little is known on effectiveness of any kind of subject matter and more attention could well be devoted towards improvement.
f. How can methods of fire prevention education be made more effective?	Do
g. What percentage of our man-caused fires are preventable?	To date no attempt has been made to estimate this percentage.
h. Should forest users be classed as "safe" and "unsafe" for fire prevention purposes?	Arguments have been presented in Fire Control Notes on this subject. No conclusions.
i. How can the knowledge of fire prevention and the safety habits of individual forest users be tested?	Do

QUESTIONS	STATUS
j. What effect would unregulated controlled burning have on the effectiveness of fire prevention effort?	Only opinion is available.
k. What physical prevention measures can be taken to cope with the habits of people that are conducive to start of fires?	Physical prevention measures based on experience are generally practiced. These include, for example, cleared parking areas, fag stations, etc.

Problem 11.

ROAD AND RIGHT-OF-WAY CONSTRUCTION AND MAINTENANCE SPECIFICATIONS TO MINIMIZE FIRE OCCURRENCE ALONG THE RIGHT-OF-WAYS

In line with the physical methods of prevention there arises the very practical question as to the probability of fires starting along railroads and power lines and on the various parts of a roadway. Cuts, fills, upside, downside, upgrade, downgrade, inside curves, outside curves, straightaways, and parking areas each may have characteristic fire-starting potentialities. Knowledge of such potentialities would dictate where clearing work should be done. Of similar importance is the widths to which roadsides and right-of-ways should be treated. These widths would depend on the cover types and the distances to which the commonly encountered firebrands will travel and still start fires.

QUESTIONS	STATUS
a. How does road location and construction influence ignition probability?	No specific information. Local experience indicates presence of some critical factors which may have important influences.
b. To what width should road right-of-ways be cleared?	Widths of clearings have been left to judgment. Ways of making savings in maintenance work are badly needed.
c. To what widths should cleared strips be maintained along roads and on what portion of the originally cleared right-of-way?	Do
d. What are the right-of-way maintenance requirements for the prevention of railroad fires?	Do
e. To what width should power line right-of-waysbe constructed?	Do
f. What cleared strips are needed on power line right-of-ways?	Do

Problem 12.

SHORT TERM PREVENTION MEASURES BEST SUITED TO HIGH FIRE DANGER RESULTING FROM DIFFERENT CAUSES

Prevention measures may be broadly general practices with a long-term view, like delivering lectures to school children and clearing roadsides, or they may be short-term steps taken to cover a brief situation, like establishing temporary closures and posting of border guards in times of unusual danger due to circumstances such as high wind, low humidity, or opening of recreational seasons. Fire danger predictions would aid the administrator in gaging the need and time for such short-term prevention measures. Moreover, the character of the prevention measure could well be made dependent on the nature of the attribute causing the danger. Thus high winds, thick haze, or excessive use, might each be met by different and specific prevention practices.

QUESTIONS	STATUS
a. What short term prevention measures are best suited to different attributes of fire danger such as high winds, low humidity, poor visibility, and excessive use?	Has been practiced on the basis of personal judgment. Analysis of all available data is needed to obtain any possibly useful information.
b. How can fire danger rating be used effectively to regulate risk?	Has been practiced on the basis of personal judgment. Experience with present fire danger rating systems has not resulted in outstanding developments.

Problem 13.

THE RELATION BETWEEN IGNITION PROBABILITY AND THE PHYSICAL CONDITIONS OF WEATHER, FUEL, TOPOGRAPHY, AND USE WHICH INFLUENCE THE MANNER IN WHICH FIRES START

An accurate knowledge of the conditions under which fires are most apt to start would permit the administrator to intensify his prevention efforts when they are most needed, and to stress the particularly dangerous conditions in his educational program. Such knowledge would even allow intelligent alteration of the character or arrangement of the fuels in the forest to lessen the probabilities of ignition.

QUESTION	STATUS
a. Under what conditions do fires start?	It is usually agreed that varying conditions of wind, humidity, fuel moisture, air and fuel temperature, topography, kind, arrangement, and herbaceous stage of the vegetation, kind of firebrand, and human use of the forest, influence the probability of or ease with which forest fires start. In a general way it is known how each of these factors contribute, but it is not precisely known how the probability of ignition varies with variations of these variables or of combinations of these variables.

Problem 14.

THE CONDITIONS UNDER WHICH FIRE MAY BE USED AS A MANAGEMENT TOOL WITHOUT UNDUE RISK TO ADJACENT FOREST AREAS

Occasions arise in forest management when fire may advantageously and economically be used for such purposes as slash and snag disposal and right-of-way clearing. The use of fire as a tool necessitates accurate knowledge of conditions under which burning can be done with safety and without danger of the fire spreading beyond control.

QUESTIONS	STATUS
a. When can slash burning by various methods be done with safety to adjacent areas?	Experience and personal judgment are only present guides.
b. Under what conditions can controlled and legitimate burning be conducted without threat to adjacent areas?	Present policy is against controlled burning. Little known of the possible conditions under which it can be safely used.

Problem 15.

BEST METHOD OF RATING FIRE DANGER FOR USE IN PREVENTION WORK

Opportune timing of prevention activity is of considerable importance. If the peak of the fire load caused by known wilfulness and carelessness could be predicted and if the time lag in prevention efforts were known a more economical and effective timing and concentration of prevention effort would be possible.

It has been hypothesized that manner and intensity of forest use by humans may vary with such things as business cycles and climate fluctuations. If this is the case, predicted variations would serve as the bases for a foresighted intensification of prevention work.

Since the need for prevention work depends on the probability of fires starting in the absence of prevention, it would be advantageous if fire danger were to be so rated as to permit derivation of a measure or index of prevention need which would serve as a guide to prevention activity and expenditures.

QUESTIONS	STATUS
a. When do fires start?	Past fire records establish the general distribution of fires throughout the season. This distribution can usually be associated with major changes in certain controlling variables. Variations from day to day and with hour of the day are, however, less readily related to recognizable variable factors.
b. What should be the time relation between the peak in annual fire prevention work and the peak of fire load and the peak of forest use?	Statistical data are available on the peak of fire load and forest use, but until fire prevention effectiveness can be measured there is little hope of timing the peak in the latter.
c. On what should variation in long term prevention effort be based?	There is little information at present on any relation between these long cyclic changes and the number of preventable fires.
d. On what should variations in short term prevention effort be based?	Fire danger rating is in a state of progressive development, but as yet little attempt has been made to correlate this rating with the need for prevention endeavor. At present best left to administrative judgment.
e. How can fire danger be rated for prevention purposes?	Do

PRESUPPRESSION

To protect California forests against fire, a well-trained organization, equipped with specialized facilities, and adequate in strength is required to meet the normal fire load.

Presuppression includes all those activities concerned with the development of protection facilities, organization, and equipment, with the training of personnel, and with the placing and maintaining in a state of readiness both men and equipment needed for the suppression of fires.

The presuppression objective is preparedness. Efficient control of fires demands the placement of initial attack personnel and equipment on each fire within the time limits required by the conditions under which the fires occur — that is, within the specified hour-control limit set as the maximum allowable time from origin to attack permissible to meet the protection requirements of any given cover type or protection unit. The purpose of presuppression activity is to make the attainment of these time objectives possible by strategic planning and placement of men and equipment in the right places at the right times at a cost which must be balanced against the costs of prevention, suppression and probable damage.

An essential part of the presuppression job is protection planning, required to attain the most equitable strength of each protection activity in relation to the total cost of protection, as well as to attain a balanced presuppression unit. The strength of the combined prevention-presuppression forces required on any unit should logically be expanded to the point where additional forces do not reduce the combined costs of suppression and damage by an amount equal to the cost of their maintenance.

To carry on the planning work and to put into execution the results of planning requires a vast store of information — part of which can be derived from analysis of past fire history, but part of which must be derived from experiments designed to solve specific problems.

In this analysis, the problems encountered in the presuppression activity have been classified in four groups (a) physical facilities to handle the protection job, (b) organization of the protection forces, (c) measurement of varying need for protection, and (d) the development and improvement of recording procedures to provide a more intelligible picture of protection accomplishments and needs.

Problem 16.

DETECTION STANDARDS REQUIRED TO MEET VARYING HOUR-CONTROL NEEDS

Prompt and certain detection of forest fires is the first prerequisite for effective fire control. Since knowledge of the existence and location of a fire is the force that starts the wheels of the suppression organization in motion, it is obvious that provision for adequate detection is an activity of first importance. The time required for detection, together with that required for reporting, get-away, and travel, in large part determines the size of fire with which the suppression force must contend. As one of the elements in this elapsed time period, detection must meet certain standards and the probability and cost of reducing elapsed time by reducing detection time must be balanced with the probability and cost of making similar reductions by other means.

In searching for a plan to meet detection needs, objectives must be set up. The general statement of the requirement "adequate detection" has to be translated into concrete and specific terms to provide a tangible goal.

QUESTION	STATUS
a. What is adequate detection?	Broad regional objective set up from past fire experience and some experimental data. Localization required, particularly in different hour-control zones.

Problem 17.

THE BEST BASIS FOR PLANNING PRIMARY LOOKOUT DETECTION SYSTEMS

By and large, fire protection experience in California seems to indicate that a strong system of primary lookouts should be the backbone of the detection operation. Much thought and effort has gone into the planning and development of such systems. There are, however, still questions as to whether the basis for this development could not be improved.

QUESTIONS	STATUS
a. What criteria should govern the number and location of stations and time of manning of primary lookout systems?	Primary detection system plans were made in 1934.
b. What factors other than visible area should be used to determine the value of a lookout point?	Occurrence and values at stake taken into account in previous plans. Possibility of other governing factors open to consideration.
c. What is the value of lookouts for purposes other than detection?	Solution now by judgment only. In need of methods of measuring other values.
d. What are acceptable standards of performance for lookouts with different amounts of competition?	Critical unanswered problem, particularly in the south where few initial discoveries are by lookout observers.

Problem 18.

THE NEED FOR SUPPLEMENTARY DETECTION AND THE BEST BASIS FOR PLANNING AN EMERGENCY DETECTION SYSTEM

Experience in detection has indicated that the primary lookout system must be augmented with supplementary detection devices during periods of decreased visibility or other conditions which make efficient detection imperative. When and how to provide needed additional detection facilities is an important problem.

QUESTIONS	STATUS
a. What is the effective range of lookouts under different conditions?	Estimates of individuals employed at present. Instrumental development and haze measurements are needed.
b. Are lookout systems always the best method of obtaining dependable detection?	A frequent point of debate locally. No absolute measures yet available for measuring relative values.
c. What criteria should determine the time and strength of manning of an emergency detection system?	Plans for emergency system and criteria for their manning need additional study.
d. When and how should airplanes be used for detection?	Airplanes used frequently following lightning storms. Their reliability is yet uncertain.
e. What is a satisfactory method of judging the detection value of patrolmen?	No satisfactory methods of evaluating have been developed. Individual estimates now employed.

Problem 19.

IMPROVEMENT OF STRUCTURES AND EQUIPMENT FOR INCREASING THE EFFICIENCY OF LOOKOUT DETECTION

The development of better structures and equipment for facilitating the proper functioning of lookouts seems to offer some possibilities for improving the efficiency of detection service. Better and more continuous visibility and better facilities to expedite the location and reporting of fires are the principal objectives toward which study should be directed.

QUESTIONS	STATUS
a. What structural development and improvement can be made to improve lookout efficiency?	Some progress in recent years. Further analysis and development warranted, with emphasis on increased vision, decreased distractions, and quicker ways of doing required operations.
b. What equipment development and improvement can increase lookout efficiency?	Do
c. Are there practical possibilities in robot detectors?	Little known of possibilities.

Problem 20.

THE BEST BASIS FOR PLANNING COMMUNICATION SYSTEMS FOR FOREST PROTECTION PURPOSES

A coordinated communication system is essential to the proper conduct of all forest administration activities. Fire protection necessitates a degree of smoothness and speed which establishes the standards for forest communication networks. Most of the fire business in California occurs within protection units having minimum hour-control time limits. Consequently, communication involved in the different elapsed time steps between discovery and dispatch of initial attack forces must be a matter of only minutes and seconds to permit achievement of the objective.

Communication plans for permanent networks must be based upon the necessity for linking together the different units of the protection organization. At the same time, however, the final networks should provide the best facilities for making use of cooperative and other outside services essential to an efficient control job. Changes in design of communication systems must of necessity keep pace with changes in presuppression organization and with new equipment developments.

Emergency communication systems are essential to meet the temporary demands of the fire suppression job. Here the need is for a flexible system which can be adapted to a wide variety of working conditions with minimum cost and installation time. The recent development and regular use of portable radio equipment have greatly increased the effectiveness of suppression effort. Radio is still relatively new in this field, however, and much further progress is certain to be made.

QUESTIONS	STATUS
a. What are the relative speeds of different systems of communication adaptable to forest protection?	Fluctuates with new equipment developments. Telephone, radio and teletype are chief possibilities for protection use.
b. What are the relative installation, operating, and net costs of different communication facilities?	Fairly well defined although changing with current development work.
c. What influence has spacing of call boxes upon decreasing elapsed time of report?	Known to be important locally, but little information available on influence of spacing upon cooperator report time.

QUESTIONS	STATUS
d. What are the critical points in forest protection communication and how may they be eliminated or alleviated?	The problem of communication has been subjected to thorough study and intensive planning. However, possibilities still exist for improvement in speed and reliability. Most of the critical points are recognized and could be eliminated with ample funds. Without them the problem remains static.
e. What are the relative merits of different communication systems for detection, dispatching and suppression?	Further analysis warranted as additional new equipment, and finances become available.
f. How can emergency communication networks for fire suppression use be made more effective?	Present instruments need perfecting. New instruments are being developed at the Radio Laboratory. These will, in time, permit development of more serviceable suppression networks.
g. How can mobile radio units best fit into emergency communication networks?	This is a new field in forest protection and little is known of the ultimate possibilities.

Problem 21.

THE BEST BASIS FOR PLANNING A TRANSPORTATION SYSTEM FOR FOREST PROTECTION PURPOSES

Problem 22.

THE PROPER ROLE OF FIREBREAKS IN FOREST PROTECTION AND THE BEST BASIS FOR PLANNING A FIREBREAK SYSTEM

The development of roads, ways, and firebreaks over which suppression forces must travel to reach a fire has been for many years an integral part of fire protection. The intensity of development has usually been based on travel requirements of the expected fire business. More recently the concept of road development has been enlarged to include consideration of the other uses to which roads may be put and the needs of other forest activities, such as utilization and recreation. These "all purpose" transportation plans aim to give due weight to all uses and plan locations, specifications, and development so as to meet best the over-all needs.

Assuming a basic network of the necessary protection roads there remains the question of the proper complement of ways, including trails, and firebreaks to go with it. In transportation, as elsewhere in the protection set-up, speed is essential. The specified speed of initial attack governs the time allowed for travel, and consequently, specific road requirements. Road specifications and patterns must therefore be designed to meet those requirements through integration of distances, road standards, and equipment performance. These relationships and their influence on protection achievement present critical planning problems.

Transportation planning must also consider, in addition to travel requirements, other uses to which the facilities may be put. Outstanding among these is the use of the network to facilitate the suppression of fires that escape the initial attack stage. The relative weight to be ascribed to this use must vary with cover, topography, and locality, and the ascribed weight should then influence the extent to which the system be modified.

QUESTIONS	STATUS
a. What elements define protection needs for transportation facilities?	Inflammability, occurrence and other elements used as basis for present plans. Probably possible to strengthen and refine bases.
b. What weight should fire protection be given in all-purpose transportation planning?	Based on judgment. More refined methods needed.

QUESTIONS	STATUS
c. What considerations should establish the specific location and standards of primary protection roads, ways, and firebreaks?	Present plans based on time demands for initial attack and reinforcements and possible use as control lines. Possibly there are other important factors to be considered, and new methods of weighting.
d. What are the critical limiting factors governing current travel speeds and how can they be alleviated or eliminated?	No systematic study completed. Some data available from field road logs.
e. How is the distribution and strength of manning of suppression stations related to transportation facilities?	Various methods developed for past planning both in California and other regions based on available data. Improvements can still be made.
f. What improvements can be made on new equipment developed to increase transportation efficiency?	Equipment now in use is generally conventional. A reanalysis of needs might bring new equipment and lower costs.
g. What types of airplanes and what parachute techniques can be adapted to increase transportation speed and facility in forested country?	The proper place of this method of transport in fire protection remains to be worked out. Parachuting technique developing rapidly in other regions.
h. What are the relative economies and advantages between protection roads, ways, including contour trails, and firebreaks as transportation facilities?	Some information available but no complete system for evaluation worked out.
i. What are the relative economies and advantages of protection roads, ways and firebreaks as possible control lines?	Do
j. What relative weights should be assigned to the values of roads, ways, and firebreaks as transportation facilities and as control lines in transportation planning?	Do

Problem 23.

THE BEST METHODS FOR SECURING WATER-STORAGE FACILITIES FOR SUPPRESSION PURPOSES

The use of water in fire suppression has increased tremendously during the past few years. The development of tank truck equipment has been particularly far reaching in its effect on fire suppression practices and related presuppression needs. The growing use of this equipment has increased the need for water-storage facilities especially in locations where natural supplies are inadequate.

Water development plans must logically conform to existing and planned transportation facilities. Within this limitation there are questions of both proper distribution and type of development best suited to the probable needs for suppression under different conditions of availability of water, kind of cover and topography, and probable fire business.

QUESTIONS	STATUS
a. How can proper spacing of water facilities be accomplished?	Some plans developed. Systematic procedure required.
b. Is it feasible to employ storage tanks to which water must be hauled? If so, what distribution is warranted?	Already done in some areas. Possibilities of extension where analysis warrants. Needs further study for justification.
c. What are the relative economies and advantages of storage tanks with catchment basins and storage tanks that must be filled?	Systematic study needed to make the comparison. Structural and cost data on each type are available.

Problem 24.

EQUIPMENT BEST SUITED TO THE DIFFERENT PRESUPPRESSION AND FIRE SUPPRESSION JOBS

Equipment development and its widespread application to the specialized needs of fire control have contributed in no small part to the greatly increased efficiency of fire protection work during past years. The needs for specialized equipment are as numerous as the many operations involved in the administration of a protection unit. Detection, communication, transportation, dispatching, fire fighting, and servicing of fire suppression manpower are quite different in equipment demands.

Although much equipment has been adapted in recent years from other fields and many new pieces of equipment have been developed, wholly suitable items for many of our specialized jobs are lacking. There still remain many opportunities for equipment adaptation, modification, and invention.

QUESTIONS	STATUS
a. What are the suppression equipment needs and how well are they met?	Needs are being slowly met as they are recognized. Comprehensive analysis and pooling of effort might be desirable.
b. What equipment, development, and improvement can increase lookout detection efficiency?	Developments sporadic, largely through individual effort. Nature of lookout job merits special attention.
c. What elements govern the selection of transportation equipment to be used for different fire protection jobs?	Equipment now in use is generally conventional. Reanalyses of needs might bring new equipment and lower costs.
d. What are the comparative advantages of existing pieces of equipment used for the same suppression purposes?	Some general information available but more specific and extensive data needed.
e. How can development of new and improved equipment be stimulated?	Stimulus now is recognition of needs by many individuals. There may be a place for a more systematized concerted attack.
f. How should standardization of water using equipment and accessories be achieved?	Some work has been done but the field has not been entirely covered.

Problem 25.

THE BEST SYSTEM FOR APPORTIONING FIRE EQUIPMENT AMONG DIFFERENT PROTECTION UNITS

Determination of equipment needs and distribution of equipment within a protection unit are two of the major problems encountered in protection planning. Only by thorough analysis of the whole protection problem is it possible to determine the best balance in quantity and distribution of these facilities.

QUESTION	STATUS
a. How should fire equipment be apportioned among different protection units?	Done currently by methods which have gradually evolved. Possibility of adding new factors and developing more exact method of integration.

Problem 26.

THE BEST METHODS FOR FINANCING, SERVICING, AND MAINTAINING FIRE EQUIPMENT

The storage and maintenance of fire control equipment stocks is a major problem of concern to most protection agencies. Investments are normally heavy on busy fire units and equipment depreciation rates are high. The financial aspects of this combination frequently present a critical problem.

QUESTIONS	STATUS
a. How can the best servicing of fire equipment be secured and insured?	Present methods fairly well established on basis of general experience. Further improvement is needed.
b. How can loss and damage of fire equipment be reduced?	Do
c. What financing arrangements can be made to improve present procedures of maintenance and replacement of necessary fire stocks?	A real problem requiring intensive study.

Problem 27.

THE BEST METHODS FOR WAREHOUSING AND PACKAGING OF FIRE EQUIPMENT

On different fire protection units in California there are nearly as many methods of warehousing and handling fire equipment as there are kinds of fire equipment. Some advanced methods are more efficient than others, but here too, there is much room for improvement.

QUESTIONS	STATUS
a. What are the relative advantages of centralized and decentralized warehousing of fire suppression equipment?	Both methods used. Questions exist as to advantages for given sets of conditions.
b. How can best arrangements and systems of packaging fire equipment be determined?	Many procedures used. Study might pay dividends in efficiency.
c. Should arrangement and packaging of fire stocks in warehouses be standardized?	Do
d. What rations should be included in fire warehouse stocks?	Practice varies. Questions arise as to what is best for a given set of conditions.

Problem 28.

THE BEST BASIS FOR PLANNING THE DISTRIBUTION AND STRENGTH OF MANNING OF FIREMAN STATIONS, INCLUDING THE LOCATION AND ASSIGNMENT OF TANK TRUCKS

The numbers of different kinds of protection positions and their distribution within a protection unit should be sufficient to meet the hour-control requirements for all parts of the unit. Determination of the size and structure of the personnel organization necessary to meet these requirements most efficiently and economically under varying conditions of weather and inflammability is without question the most important protection planning problem and the one in most urgent need of solution.

The history of past fire business and the degree of success or failure with which existing presuppression organizations attained the fire control objectives are as yet the only sound basis available for planning work. But fire control objectives have not been static, nor have fire load and protection methods. Changing objectives, climate, cover type, use, methods, equipment and many other factors all render the story of the past an incomplete index of what will happen in the future. The value of fire history as a planning tool used to indicate trends, however, should not be minimized.

Solution of the more important problems which arise in planning the proper size and structure of a presuppression organization must therefore depend upon a wider field of information than the history of the past. Theoretical analysis, the accumulation of experimental values for present unknown variables, and the use of pertinent experience gained in other fields, offer the only apparent means for obtaining the additional needed information.

QUESTIONS	STATUS
a. What is the minimum level of fire business which warrants a specified hour control coverage?	Present practice governed by past experience and judgment. Refinements may be possible through study.
b. What conditions define the level of protection (speed and strength of attack) to be used as a planning basis?	Analysis of past accomplishment records has provided partial answers. Records are not sufficiently detailed to be wholly satisfactory except for broad zones.
c. How should forest management requirements influence structure of protection organization?	Taken into account in a general way. More specific data probably obtainable.

PRESUPPRESSION - ORGANIZATION - STRUCTURE AND FUNCTIONS

QUESTIONS	STATUS
d. What criteria should govern the distribution and strength of manning of fireman stations?	Has been governed in the past by needs as far as they could be determined from available data. More exact methods are needed.
e. What is the optimum elapsed time between origin and initial attack for use as a basis for planning a protection organization?	Maximums have been specified through analysis of experience. Optimums have never been adequately defined.
f. What is the maximum size of fire at initial attack for use as a basis for planning a protection organization?	Existing data derived from past experience. Could be determined experimentally.
g. What conditions should determine the balance between the number of one- or two-man stations and the number of crew stations?	Considered in all previous planning on basis of past experience and available data. No specific tests or experiments made.
h. What is the optimum size of crew for initial attack?	Experience only used in past planning. Might better be determined experimentally.
i. What is the most economical distribution of total elapsed time between the steps of detection, report, getaway and travel?	Never thoroughly investigated. Holds possibilities. Present regional standards in need of revision.
j. What are the relative advantages of centralized and decentralized control over protection facilities?	Both kinds in California. Individual advantages of each have been recognized, but little toward their evaluation has been done.
k. What is the manpower equivalent of a tank truck, and what is the best balance between manpower and tank truck strength and distribution?	At present there is no method for ascertaining relative merits. A matter of personal judgment.

Problem 29.

THE BEST BALANCE BETWEEN INTENSITY OF PROTECTION AND THE FLUCTUATING NEED FOR PROTECTION

Protection planning involves a number of decisions pertaining to protection personnel requirements. First, the total number and distribution of stations needed for detection and initial attack; second, whether the stations should be manned by single men or crews; and third, what stations should be manned and with what strength under varying conditions of fire danger.

Average opening and closing dates of the fire season recognized by the occurrence or non-occurrence of fires are the usual basis upon which short-term protection positions are authorized. The departures of individual years from the average, however, lead to either serious overmanning or undermanning during spring and fall periods if these average dates are allowed to govern. Because authorized protection strength is that judged adequate for most, but not all, bad days during the more difficult years, over- or under manning may also result from uniform application of authorized strength throughout the actual fire season. Efficient management requires that adequate protection be provided without unnecessary overmanning. The method by which the balance can best be maintained constitutes an important problem.

QUESTIONS	STATUS
a. How can wide fluctuations in the strength of manning be secured to maintain the balance between intensity of protection and the fluctuating need for protection?	Some fluctuation now but methods of securing greater variations needed.
b. Can seasonal outlooks or long-range forecasts be used to advantage in planning protection organization?	Not done at present but may have relatively great possibilities with sufficient improvement in forecasts.
c. How should varying fire danger govern the strength and structure of the protection organization?	Experience in this has been within the past few years. With more experience better correlation can be developed.
d. How should varying fire danger govern the prevention and presuppression activities?	Based on judgment during past years. More exact basis would be an improvement.
e. How can weather forecasts be used in conjunction with fire danger rating to vary the organization structure and functions?	Experience in this has been within the past few years. More experience and better methods are needed.

Problem 30.

REDUCTION IN LARGE TURNOVER OF SHORT-TERM PERSONNEL

The personnel problems in fire control in California are mainly concerned with two groups. The first is the yearlong administrative group in which training is the primary concern. The second is the much larger force of seasonal employees filling the numerous presuppression positions and presenting an annual problem of selection, training, and maintenance.

The qualifications and training of the temporary personnel selected for the presuppression positions play a critical part in determining the success or failure of fire protection effort. The problem of personnel management in this field is of considerable concern and occupies an important position in the presuppression program because of high turnover and short time available in which to condition and train the men and perfect a smoothly running organization.

How to hold good men in the seasonal presuppression jobs is one of the biggest stumbling blocks at the present time. Solution of this problem can be expected to do much toward helping solve the other problems.

QUESTIONS	STATUS
a. What qualifications are necessary for different short-term fire control positions?	Present qualifications not standardized with exception of those covered by guard examinations. Individual positions need additional study.
b. What kinds of personnel are best adapted to crew and one-man stations?	Job analyses are needed.
c. How should short-term personnel be integrated in the service to reduce present excessive turnover?	Much thought has gone into this problem but little has been accomplished. Difficulties appear to be largely financial.
d. In what positions can college students be used to the greatest advantage?	Present system of assigning students based largely on experience. Additional job analysis might be beneficial to both individual and organization.

Problem 31.

MAINTAINING PHYSICAL FITNESS AND GENERAL EFFICIENCY OF PROTECTION PERSONNEL

Fire suppression is strenuous work which often calls for the expenditure of much energy within a short period of time. The activities of protection personnel between suppression jobs are not generally such as to maintain the best physical condition. While it is not hoped to eliminate physical and mental exhaustion from firefighting, their onset can assuredly be postponed by known means, and certainly more fires prevented from getting away.

QUESTIONS	STATUS
a. Would there be any advantage in supervising and regulating the diet of protection personnel?	Study needed to indicate specific advantages.
b. How does fatigue influence manpower output in fire suppression?	Very small amount of factual information available. Good data highly important in strategy, ordering men on large fires, and in planning relief on the fireline.
c. How can fire protection personnel be kept in good physical condition?	The problem is frequently a serious one applying to both regular and short term personnel.
d. What are the best methods for insuring lookout efficiency?	Some management devices now used. Field needs further exploration.

Problem 32.

TRAINING OF SHORT-TERM PROTECTION PERSONNEL: INCLUDING APPRAISAL OF NEEDS FOR TRAINING, METHODS OF TRAINING, AND EVALUATION OF THE EFFECTIVENESS OF TRAINING

The occurrence of fires that are not held to small acreage by initial attack forces may still in some cases be attributed to inadequate training of short-term protection personnel. Improper attack is the generally ascribed cause of fires getting away. A less readily ascertainable cause undoubtedly occurs more or less frequently through failure of lookout detection personnel to discover all fires in the minimum possible time. Many advances in training procedure have taken place in recent years, but the whole field is still in need of intensive development.

A question closely related to that of training the regular short-term personnel is that of training equipment operators, crew leaders, laborers, and other emergency forces.

QUESTIONS	STATUS
a. How can the current need for training be measured?	Inspection does it by judgment. More systematic method is needed.
b. Who should be given fire protection training?	Various men, other than regular and short-term fire personnel, are now trained. Question is are the right men being trained for the right jobs.
c. When should short-term personnel be given protection training?	Now given at guard schools and through periodic inspection. Question if formal training is needed at other times.
d. For what specific large fire suppression jobs should guard personnel be trained?	Requires study of jobs and men's capabilities to fit the two together insofar as possible.
e. What training methods are applicable to the occupants of different protection positions?	Methods now more or less standardized. Efficiency might be increased by tailoring methods to the job.
f. What are the weaknesses in the present training methods?	In spite of any advances this should be a perennial question.
g. What new or improved training methods can better meet fire protection needs?	Do
h. How can the effectiveness of training be evaluated?	Improved methods are needed to evaluate properly the advantages of different methods.

QUESTIONS	STATUS
i. Who should be responsible for training?	Done by practically all regular personnel. It could probably be done more efficiently by admitting that some men are poor teachers.
j. What are the relative advantages of using training teams and the system of employing all regular personnel as trainers?	Do
k. What proportion of the protection job, in terms of finances, time, and energy should be devoted to training?	It can probably be assumed that in general there is given only minimum essential training, particularly to short-term men.
l. How can individually accumulated experience in fire suppression best be made available for training purposes?	Now done through boards of review and hand books. Special study needed.
m. How can improvement equipment operators be given effective training to meet specialized suppression needs?	Apparently a need for systematic plan. Improvement work does not provide all the needed training.
n. How can hired fire suppression labor be trained effectively on the job?	Methods available. Need is for an orderly procedure to insure application of present methods as well as for development of new ones.

Problem 33.

TRAINING OF REGULAR PERSONNEL; INCLUDING EVALUATION OF THE NEEDS FOR TRAINING, METHODS OF TRAINING, AND SELECTION OF MEN FOR HIGHER TRAINING

The problem of training regular yearlong personnel in the rudiments of fire fighting is in many respects similar to that of training the short-term force. But the wider responsibilities of the regular men require that their training be carried deeper into basic principles and farther into the field of protection management. The problem of training fire generals is particularly acute. All of the present best fire bosses are seasoned men who have secured their training through long years of experience at uncalculable costs of suppression and damage. The great differences between seasoned and inexperienced performance make consideration of this problem of first importance.

QUESTIONS	STATUS
a. How can regular personnel be selected for higher training?	Now done on judgment. Probable that specific tests could be devised.
b. What basic education, as in mathematics and science, is desirable and essential for men in key fire control positions?	Unanswered at the present time.
c. To what extent should training in management be included in protection training?	Requires study of how well present training meets management needs. Management of large fires indicates need for further development.
d. Should individuals be trained to become specialists in specific fire suppression staff jobs?	A study of advantages and disadvantages would be desirable. These hinge upon structure of organization accepted for suppression work, and upon aptitudes of available personnel.
e. To what extent is it desirable to train overhead in the operation of equipment?	Study needed on what such training would accomplish.
f. How can the results of training effort be evaluated?	No systematic procedure used.
g. What can schools do to contribute to the solution of the protection training problems?	Protection training perhaps not now given the weight it deserves or may be pointed in wrong direction. Study needed to effect desired changes within pattern of modern college education.

PRESUPPRESSION - ORGANIZATION - PERSONNEL

QUESTIONS	STATUS
h. How can burned areas be employed in suppression training?	In some regions used as classroom. Why not here?
i. How can going fires be used to best advantage in training men for overhead positions?	At the present time men are usually assigned to specific jobs.
j. To what extent should fire suppression overhead teams be trained?	Question still open as to practicability and results.
k. When should regular personnel be given protection training?	At present given at guard schools, at going fires, at boards of review, ranger meetings, and details to fire schools, most of which are governed in time by factors other than most desirable training times.

Problem 34.

SECURING THE COOPERATION WHICH WILL RESULT IN MOST EFFICIENT PROTECTION

Fire suppression is an emergency activity frequently requiring manpower and equipment over and above the facilities available within the organization. Speed in the procurement of these facilities is essential, just as in other phases of the suppression job. The protection plan for any unit should therefore anticipate the possible needs for additional men and equipment and should set up the procedure for obtaining them which will result in the least possible delay in time of need.

The manpower and other facilities of outside individuals and agencies and of other protection units are possible sources of aid. Essential parts of the presuppression job are: first, to locate the sources of supply; second, to secure in advance the cooperation of these individuals and agencies in making their services available with minimum delay when needed, and third, to organize the cooperative facilities so as to make them more effective.

Cooperation of the public in discovery and early report of fires is a valuable service that is probably often much underrated in protection work. There are undoubtedly many ways in which public cooperation could be further developed and encouraged.

QUESTIONS	STATUS
a. What forms of cooperation can be made available for different protection purposes, such as prevention, detection, and suppression?	Considered annually in fire plan revisions. Possibilities of new and better approaches and methods need study. Present practices are well ahead of other protection activities.
b. From what sources can cooperation be enlisted for different protection activities?	Do
c. How can cooperation be secured from different agencies?	Do
d. What obligations are entailed through securing cooperation?	Do
e. When should cooperative agreements be made with other agencies?	Do
f. How can protection facilities of adjacent protection units be utilized in emergency with least delay?	Cared for by present plans to large extent. New and better methods might be developed.
g. What means may be provided to induce public aid in reporting fires?	In some places through phones in cooperators' buildings, in some through call boxes placed along roads. Possible that utilization of these and other means have not been developed to point of greatest effectiveness.

Problem 35.

DEVELOPMENT OF FIRE SUPPRESSION PLANS AS A PRESUPPRESSION ACTIVITY WHICH WILL MAKE SUBSEQUENT FIRE SUPPRESSION ACTION MOST EFFICIENT

Fire suppression action would presumably be much more effective if much of the planning usually done after the start of a fire could be done in advance. The conditions which dictate the specific action to be taken on each fire are numerous, and many of them cannot be foreseen until the suppression job is at hand. Nevertheless there are unlimited possibilities for planning those phases of the job that can be foreseen.

The problems involved in suppression planning are resolved from two primary considerations: (1) the probable behavior of a given fire under assumed weather conditions; and (2) the suppression strategy, organization, and facilities which would be required to cope with the fire under the conditions assumed.

QUESTIONS	STATUS
a. Of what should a suppression plan consist?	Plans have been made for a number of years but need further development with much greater detail.
b. How can knowledge of fire danger be used to best advantage in suppression planning?	More exact methods of measurement and interpretation are needed.
c. How can pre-fire scouting be done and the results made readily available for use?	Practically none done systematically. Appears to offer distinct possibilities.
d. How can accumulated experience in fire suppression best be used in suppression planning?	Possibility of improving methods of making the accumulated experience more available.
e. To what extent should fire suppression organization plans be developed in advance?	Tried in some places with varying success. May offer more possibilities than is generally supposed.
f. What measures of performance of manpower and equipment best meet the needs of suppression planning?	Now usually expressed as chains of held line. Not entirely satisfactory.
g. To what extent should there be fire-camp surveys and development?	Some informal surveys have been made.
h. How can plans for specific equipment needs and equipment placement be made in advance?	An important phase of pre-fire scouting; more systematic procedure might be devised.

QUESTIONS	STATUS
i. How should dispatching for individual fires be planned in advance?	Now largely done at the time of fire. More advance planning desirable.
j. How can proper spacing of water facilities be determined?	Analysis of suppression needs indicated.

Problem 36.

THE EXTENT TO WHICH THE PROTECTION WORK OF DIFFERENT AGENCIES SHOULD BE COORDINATED TO SECURE MAXIMUM PROTECTION AT LOWEST TOTAL COST

Part of the coordination required in fire protection is considered under cooperation. There are still broader fields to be covered however, such as coordination of prevention programs, law enforcement, and standardization of methods and equipment, in which coordinated effort might result in definite benefits.

QUESTION	STATUS
a. To what extent should the protection functions of different agencies be coordinated.	Much progress has been made in this field. Still room for improvement.

Problem 37.

EQUITABLE DISTRIBUTION OF FIRE CONTROL ALLOTMENTS BETWEEN PROTECTION UNITS

Different protection units, whether they be forests, counties, or ranger districts, require different amounts of protection because of differences in climate, cover, topography, values, and use, and because of different systems of land management under which the protection must be provided.

QUESTION	STATUS
a. On what basis should allotments between protection units be distributed?	Done on the basis of judgment applied to many factors. Possible to devise more mechanical system to secure consistent results. Fire danger records will help.

Problem 38.

SECURING AN EFFICIENT BALANCE BETWEEN THE PROTECTION ACTIVITIES OF PREVENTION, PRESUPPRESSION, AND SUPPRESSION

Problem 39.

SECURING A BALANCED PRESUPPRESSION ORGANIZATION

In sound land management, protection allotments should be made in proportion to protection needs. Coordination of fire control expenditures between units and between activities within units is essential to this end. On no other basis can fire control objectives be attained within a reasonable and justifiable cost.

QUESTIONS	STATUS
a. On what basis should protection effort and expenditures be distributed between the protection activities of (a) prevention, (b) presuppression, and (c) suppression?	Now balanced by judgment. Detailed economic study needed.
b. What are the criteria and processes by which a balanced protection organization may be established?	Would require special study to itemize and weigh all factors.
c. How can the results of different presuppression activities be evaluated?	No accurate methods now available.
d. How can presuppression units be managed to handle other activities?	Done to varying extent now. Subject needs to be explored further.
e. What priorities or relative weights should govern apportionment of funds for personnel, improvements, equipment, and other fire control facilities in a presuppression program? For example, suppression crew strength versus tank trucks.	No method now in use other than judgment and organization policy.

Problem 40.

THE BEST PERSONNEL MANAGEMENT METHODS TO GET BETTER PERFORMANCE IN FIRE CONTROL

The problems of coordination in forest protection involve principles of business management as well as technical aspects of the protection job. They concern mainly the extent to which activities should be made to conform to given patterns, methods of evaluating the benefits to be expected from different combinations of methods and procedures, and ways in which compliance with approved practices can be secured.

QUESTIONS	STATUS
a. To what extent can job analyses and work plans aid in protection management?	In use now. Methods need revision.
b. To what extent should improvement and other personnel be trained and used in fire protection? What are the obligations of those units to protection?	In some places considerable training and use now. Careful consideration of obligations might extend both.
c. To what extent should training methods and devices be standardized?	Fairly well standardized now. More variety might be beneficial.
d. How can better coordination be secured through boards of review?	More study needed.
e. What inspection methods pay the biggest dividends in better performance?	A number of inspection methods now in use. Would require special study for improvement.
f. What management devices in addition to training can best insure compliance with performance standards and insure the application of available knowledge in all fire control activities?	There are a number of means now in use, but these still do not prevent breakdowns of the fire-fighting machine.

PRESUPPRESSION - FIRE DANGER - VALUES

Problem 41.

THE MANNER IN WHICH VALUES, THEIR OWNERSHIP, AND THEIR SUSCEPTIBILITY TO DAMAGE AFFECT THE INTENSITY OF NECESSARY FIRE PROTECTION AND THE CORRESPONDING PRESUPPRESSION ACTIVITY

Since fire danger is not only danger of fire occurrence, but, more than that, it is danger of fire damage, value must be one of the main quantities dictating the need for protection. It is not known, however, just what weight value should carry in comparison with the other factors influencing protection need. One of the reasons for this is the lack of any acceptable system for appraising all the values of a given area. Some of the more obvious values, for example that of merchantable timber, can be appraised but there are others, such as watershed and recreational values, for which no satisfactory method exists. Not only are the total actual values being protected in doubt but there is equal uncertainty as to the relative destructibility of these unknown assets. In addition to problems on the estimation of values and their destructibility, there are other puzzling questions which need answering, especially those pertaining to the public values on privately owned land.

QUESTIONS	STATUS
a. To what extent should values influence total fire danger and, correspondingly, presuppression planning and activities?	Taken into account in presuppression planning. Whether to proper extent is not exactly known.
b. What values should be taken into consideration in establishing the need for protection and how should they be integrated?	Major significant values usually taken into account in presuppression planning. Question of completeness and method of combination.
c. How should values at stake be measured?	Exact methods of measurement not known.
d. To what extent should probable effects influence total fire danger, and correspondingly, presuppression planning and activities?	Probable effects of fire are not formally weighted although given consideration locally in development of presuppression plans. Of outstanding significance in planning protection in connection with flood control.
e. Should ownership of values at stake influence presuppression planning or activity?	Influences planning some extent; whether in proper manner or to proper extent is not known.

Problem 42.

THE MANNER IN WHICH PROBABLE FIRE OCCURRENCE AFFECTS THE INTENSITY OF NECESSARY FIRE PROTECTION AND THE CORRESPONDING PRESUPPRESSION ACTIVITY

Satisfactory estimation of the risk of fires starting is essential to sound presuppression planning. The average level of fire business, as taken from fire records, establishes the normal distribution and strength of presuppression facilities. Seasonal and short time variations in the planned distribution and strength of these facilities required to maintain a balance between protection strength and current need for protection, on the other hand, require estimates which cannot be based on past records alone. For these estimates a knowledge is required of the causes of variations in potency of firebrands as well as in ignitibility of different fuels, and a knowledge of how the effects of these causes can be measured and integrated. Risk maps, for example, now used extensively in presuppression planning could be subjected to much needed improvement if a sound basic classification of fuels with respect to ignition probabilities were available.

QUESTIONS	STATUS
a. To what extent should fire expectancy influence presuppression planning activities?	Best available estimates used in planning, but there may be a better method of weighting risk.
b. How can fire expectancy be satisfactorily estimated?	Largely done on the basis of occurrence and use. Much better formulae needed.
c. What variables influence probability of ignition?	Some work has been done on the limits of certain variables within which ignition is possible. Probabilities need investigation.
d. How does ignitibility of various fuels vary with time?	Partially solved in some regions; in California intensive study needed.
e. What criteria should be used in determining fuel types for ignition purposes?	Usually done on the basis of general cover. With more knowledge of ignition factors a more exact system will be possible.
f. Would special fuel type surveys be justified?	Not done in California. Considered important in some other regions.
g. What is the relation between forest use and probability of fire starting in various fuel types?	Little information available but badly needed.
h. How does topography influence fire ignition?	Some general knowledge but more detail needed for greater usefulness.

Problem 43.

THE MANNER IN WHICH PROBABLE RATE OF SPREAD AFFECTS THE INTENSITY OF NECESSARY FIRE PROTECTION AND THE CORRESPONDING PRESUPPRESSION ACTIVITY

The rates at which fires spread should play an important role in nearly all protection planning work. Rate of spread under "average worst" conditions is one of the three main factors (along with values at stake, and resistance to control) governing the basic speed and strength of initial attack prescribed for different cover and fuel types and upon which protection authorizations are based. It is further recognized as the principal variable fire danger factor determining short time fluctuations in organization strength required to meet the fire control objective.

Both planning work and rating of current danger necessitate estimates of the rates at which anticipated fires will spread. This can be done only by understanding the manner of dependence of rate of spread on its more fundamental governing factors, and then by measuring and integrating these factors in the field. Fuel types, topography, etc., should be classified for fire danger purposes in accordance with the quantitative manner in which each of these specific variables influences rate of spread. The behavior of past fire has not provided the complete answer to this important problem because the essential information has not been recorded.

QUESTIONS	STATUS
a. What variables influence rate of spread of fire?	More significant variables generally recognized, but information on ways of measuring some of them and on the combined effects of different variables on rate of spread is very meager.
b. How does time from origin of fire affect the rate of spread?	Little information available.
c. What criteria should be used in determining fuel type for spread purposes.	For reliable typing more study is needed. In absence of basic information on fuel criteria, fuel type mapping has not been considered justifiable.
d. How does rate of spread vary with the volume and condition of the green vegetation?	No reasonably exact data available.

Problem 44.

THE MANNER IN WHICH DIFFICULTY OF CONTROL AFFECTS THE INTENSITY OF NECESSARY FIRE PROTECTION AND THE CORRESPONDING PRESUPPRESSION ACTIVITY

The problem of determining number of men and quantity of equipment required to execute a given suppression job is primarily one of length of control line and difficulty of constructing and holding that line. The problem of primary concern in this connection is in classifying areas so that the suppression production to be expected from unit effort can be computed from the classification.

QUESTIONS	STATUS
a. What measure or measures of resistance to control are best suited to use for fire protection planning purposes?	Area or length of line per man per unit time is now used. There may be more satisfactory measures.
b. What variables influence resistance to control?	More obvious factors known; greater refinement would take more study. No quantitative measure of the influence of the variables is available.
c. What criteria should be used in determining fuel types for resistance to control purposes?	Do

Problem 45.

THE NEEDS FIRE DANGER RATING MUST FILL AND THE BEST METHODS OF ESTIMATING FIRE DANGER FOR THESE PURPOSES

The season-long maintenance of a protection organization at sufficient strength to handle the worst probable danger would not be economical. For this reason it is preferable to strengthen the basic organization during these high danger periods in which most of the large and damaging fires occur.

During high danger it may be advisable to invoke special prevention precautions, to strengthen the presuppression organization by one means or another, or to increase both initial attack and follow-up forces in fire suppression. Similarly, it is just as important to reduce stand-by forces below the basic level when favorable conditions warrant this reverse action.

During recent years there has been a rapid development in methods for estimating the daily status of the variable portion of fire danger, and for forecasting changes. Besides furnishing a valuable tool by which to gage current need for given intensity of protection, there are a number of additional possible uses of danger rating measures and records. Outstanding among these are for comparing the protection loads between different units and seasons, for appraising protection efficiency, and for guiding the allotment of protection funds.

The fire danger rating systems used in various Regions at the present time have been developed empirically to meet regional needs. This has resulted in wide differences in the scales of danger employed as well as in material differences in the manner in which the various factors are integrated. Most of the systems have been developed in this way because of lack of the data required to place them on a sound factual basis. The need for further information, particularly in fire behavior and difficulty of control, is everywhere recognized.

QUESTIONS	STATUS
a. What are the specific purposes of fire danger rating?	Generally recognized. Perhaps better definition needed.
b. How can fire danger be rated for different purposes?	Now largely on empirical basis. More factual information needed for sounder basis.
c. What elements control the different measurements of fire danger?	Do
d. How should the fire danger rating elements be measured?	Do
e. How should the fire danger rating elements be sampled?	Do

QUESTIONS	STATUS
f. How should the fire danger rating elements be integrated for fire danger measurements?	Improved currently as better information becomes available.
g. What are the relative advantages of indexes and absolute values?	Needs detailed study.
h. What is the relative advantage of "normal" versus other possible indexes?	Do
i. How can lightning fire forecasts be integrated into fire danger rating?	Do
j. What modifications of fire danger rating are necessary for pre- and post-season conditions?	Present basis unsatisfactory. Needs special study.
k. To what extent can fire danger rating be standardized to serve both national and local needs?	Current project led by W. O. fire control. Warrants considerable attention.
l. What measure of fire danger will satisfy both national and local needs?	Do
m. What fire danger rating records are necessary and how should they be kept?	Complete records kept at individual stations. May be better methods.

Problem 46.

THE NEEDS FIRE RECORDS MUST FILL AND THE BEST METHODS FOR COMPILING AND ANALYZING THE REQUIRED DATA

Records of fire business and accomplishments in the past may be used to establish trends to serve as guides to what may be expected to happen in the future. They thus play an exceedingly important role in protection planning. To serve this need adequately, experience has indicated the necessity for accurate and complete reports, and for strict comparability in methods of reporting and compiling over relatively long periods of time and between all protection units.

The major current problems in this field are concerned with methods of reporting these elements which together tell the complete story of fire business and control accomplishments. Interpretation of records will, of course, always be an acute and vital problem.

QUESTIONS	STATUS
a. What purposes can fire records serve?	At present serve as sole factual basis for nearly all phases of protection management.
b. How can the process of accumulating and compiling fire records be simplified and improved?	There are many generally recognized difficulties in the present systems. Much additional improvement is needed.
c. What elements should be included in the fire atlas?	Reexamination of present record systems is needed.
d. How can records of individual elements be presented to give a more efficient interpretation of fire problems?	There is no romance in cold figures. Map records, too, need additional study.
e. What fire danger rating records are necessary and how should they be kept?	Three years of operation have resulted in numerous proposals with no final decision.
f. How can individually accumulated experiences in fire suppression best be made available for training and other purposes?	Handbooks and manuals form present mediums. Presentation could presumably be improved with further study.

Problem 47.

ADOPTION OF UNIFORM METHODS OF REPORTING AND COMPILING FOREST FIRE DATA BY THE DIFFERENT PROTECTION AGENCIES

Not only is it necessary that any given agency maintain accurate and consistent fire records but it is equally important that the fire business and accomplishments of different agencies be reported in such a way that identification of problems and trends is possible for the State as a whole. Because of the various responsibilities and functions of the different agencies this is not completely feasible but a great benefit would result if uniformity were introduced to the extent that it is possible.

QUESTION	STATUS
a. How can fire records of different agencies be reduced to a comparable basis?	This is an important problem of coordination between agencies. Aggressive leadership needed.

SUPPRESSION

Although many fires are prevented, there still occur numerous small and some large fires all requiring suppression action. A great deal can be and is done in preparation for those fires. But no two fires are exactly alike and each presents its own peculiar characteristics to be weighed at the crucial time.

The problems of fire suppression are resolved mainly from two circumstances: (1) the emergency nature of fire suppression, necessitating fast and energetic action with a minimum time in which to survey the problem and organize a work program; and (2) the variability of burning conditions, requiring something more than past experience alone on which to base specific suppression measures.

Experience in fire suppression has resulted in a large number of proved principles and practices. But these do not relieve the fire boss from the necessity of giving consideration to every factor and its influence on probable fire behavior, resistance to control, and effectiveness of the suppression action. To get the fire out in minimum time at a minimum suppression-plus-damage cost is a major problem of the fire control executive.

Problem 48.

THE FIRE SUPPRESSION OBJECTIVES AND POLICIES

The objectives of fire control dictate in general the specific objectives of fire suppression. In addition, analysis of past performance has shown certain well defined lines of action to be better than others. Fire control objectives together with this accumulated background of approved practices form the basis for statements of policy concerning the suppression of fires occurring under a wide variety of conditions. As additional factual information is contributed by further analysis and physical research, present statements of policy may be revised and amended.

The extent to which the resources of adjacent protection agencies may be pooled in the suppression of mutually dangerous fires occurring in proximity to protection boundaries is usually limited, at least in part, by differences in objectives and policies of the agencies concerned. Increased efficiency in suppressing these fires could probably be secured if common objectives and policies governed the suppression action.

QUESTIONS	STATUS
a. What objectives should determine policy as to suppression action on a fire and what are their relative importances?	Need further development including specific quantitative values on damage.
b. What policies should be set up so as best to meet the fire suppression objectives?	Policies are now set up, but there probably are others that would benefit protection accomplishment.
c. What management principles should be followed to carry out fire suppression policies?	Policies generally followed literally. Questionable if some specific exceptions not desirable.
d. Should fire suppression policies vary with the conditions under which fires burn?	Local exceptions to national or regional policies are not generally recognized at present. Additional study needed.
e. What should be done to remove existing difficulties resulting from differences in objectives of different protection agencies?	Current differences in suppression objectives and policies probably result at times in less effective cooperation in suppression of boundary fires than would be the case if policies and objectives were the same.

Problem 49.

THE BEST METHODS FOR MOBILIZING AND DISPATCHING MAN POWER AND EQUIPMENT FOR FIRE SUPPRESSION

The mobilization of manpower and equipment resources for suppression action is a task that can be accomplished satisfactorily only by adequate preparation before the time of need. Once the proper organization and facilities have been established, arrangements with cooperators made, and the dispatching procedures systematized, all of which are presuppression activities the mobilization and dispatching job at the time of emergency is reduced to a relatively simple function.

The problems of mobilization and dispatching are none the less real. Dispatchers must at all times know where men and equipment are located and the physical processes by which they can be secured with least delay. Particularly where reliance must be placed upon outside hired labor, dispatchers are always confronted with the problem of selecting men suitable for the suppression job and of weeding out the unfit.

The time required to determine the manpower and equipment needs, and to get them assembled and dispatched to the scene of action may vary considerably with the locality. Many aids in the form of convenient office facilities, skeleton maps showing travel routes, special forms, and other devices and procedures may be employed to speed up the job and assure that the men and equipment get off promptly and reach their destination without delay. A review of the field is needed to determine and extend the better practices.

During the period between dispatch of initial attack forces and the receipt of instructions from the fire boss, the dispatcher must assume the responsibility for mobilizing and dispatching follow-up forces. Knowledge of prevailing fire danger, conditions of topography, cover and fuel types, and information on current behavior of the fire as reported by lookouts, must all be integrated by the dispatcher to form a basis from which to determine the kinds and quantities of manpower, equipment, and overhead needed. Further development of ways in which this information may be made available in usable form and principles to be followed in applying it are badly needed to improve current practices.

Many different dispatching systems are in existence in California. They have been modified from time to time to better adapt them to local conditions and to changing protection administrations. All degrees of centralization of dispatching practice have resulted. The present situation is in need of study with the aim of revising present systems which do not perform with the most efficiency.

QUESTIONS	STATUS
a. How can men and equipment best be mobilized for fire suppression?	Present methods developed through experience dependent to a large extent on local facilities.

QUESTIONS	STATUS
b. How can work programs of improvement crews and staff men be organized to facilitate the mobilization of manpower and equipment?	Methods worked out according to local conditions. Study could identify best system in use and perhaps develop a still better one
c. What should be the minimum specifications for hired fire fighters?	General specifications given labor agents but "unfits" still appear in camps. Further study needed.
d. What dispatching aids and procedures can promote more efficient initial attack?	Many aids now available. Some systematic procedures have been developed locally. Further development and extension is needed.
e. What principles of suppression management should govern action of the dispatcher in mobilizing and dispatching forces to a fire?	Some approved practices to guide dispatcher are available. Additional development is needed.
f. Under what conditions should dispatching systems be centralized, or decentralized?	Centralized, decentralized and combinations of both are employed to varying extent between and within California protection organizations.

Problem 50.

METHODS FOR PREDICTING AND INTEGRATING FIRE BEHAVIOR AND SUPPRESSION ACCOMPLISHMENT INFORMATION NECESSARY TO PROPER PLANNING OF FIRE STRATEGY

To develop a well balanced plan of action for suppressing a fire, an orderly analysis is required of all the conditions of the fire, its environs, and the control action, which together have a combined influence on the final size of the fire and on the cost of its suppression. The processes by which the planning phase of the suppression job may be accomplished have been rather satisfactorily developed in recent years. The more important variables that must be considered have been given recognition and general principles for their applications have been evolved. But by far the majority of the information required in the development of plans is yet general in nature. As a result, planning is still impossible to the degree of certainty generally recognized as necessary to most efficient suppression.

There is usually a logical point or section of the fire which should be attacked first for such reasons as; some parts of a fire are more certain to be held than others, portions of the fire may threaten more difficult or valuable cover, or stopping the head of a fire may decrease the size of the job.

Because fires are travelling phenomona, the element of time is a most important consideration in suppression. Line construction, backfiring, and cleanup work must be done in advance of the free-burning perimeter. The plan of action should therefore specify the time limits within which these phases of the job must be accomplished to be effective. Since different parts of a fire behave differently, the requisite control action, tools and equipment, and time to accomplish each task should be planned for each part of the fire that may be expected to have significantly different requirements.

The most important planning job, following decision as to what should be done to control a fire, is to determine the manpower and equipment facilities and their distribution which will be required to put the plan into effect within the time limits prescribed by the fire behavior anticipated.

The calculated probable behavior of a fire and effectiveness of the control action must always be subject to exigencies and errors of estimate, for which there can be no basis for prediction. Efficient fire suppression must, therefore, depend on something more than ability to follow a plan of attack. No matter how well founded may be the plan of attack, there occur on nearly every large fire, opportunities which can neither be foreseen nor planned in advance, but which offer chances for major savings in area burned or time to control if immediate concerted action is taken. Such measures require the ability to recognize the possibilities when they occur, to judge quickly the chances for success with the resources available, and to execute the required action without delay.

SUPPRESSION - STRATEGY AND TACTICS

QUESTIONS	STATUS
a. How should a plan of strategy for suppression of a fire be developed?	Handbooks cover the more significant factors and planning processes. More information on their evaluation and integration needed. Volume III, Region 5 Fire Control Handbook is a valuable recent contribution.
b. What should determine the point of initial attack?	Approved practices covered by handbooks. Perhaps other factors should be considered. Problem needs review.
c. How can water, chemicals, and hand methods best be used in initial attack?	Present emphasis on use of water. Better methods of integrating the different available facilities and of improving the effectiveness of each are warranted.
d. What should determine the time objectives of control operations?	More information needed.
e. What should determine the manner in which a fire is divided into control units?	There are at present general approved practices based on present experience. Additional study is needed.
f. How can total manpower and equipment needs and their distribution between different lines and behind the line operations on different parts of the fire be determined?	Orderly processes based on present available knowledge are prescribed in handbooks. More information on fire behavior and suppression output are badly needed. Present tendency is to over-man large fast spreading fires.
g. How can fire weather forecasts best aid the planning of strategy on a going fire?	Forecasting service of the Weather Bureau is now employed in a number of ways. Improvement in use is needed.
h. When are deviations from the planned strategy warranted?	Policy is not clearly established.

Problem 51.

PROVIDING INFORMATION AND DATA NECESSARY FOR PLANNING THE DETAILED TACTICAL OPERATIONS REQUIRED TO CARRY OUT THE SUPPRESSION JOB

Line construction is normally the first suppression operation where the plan of control does not make use of already available control lines. The objective in this operation is to establish, with the least effort in the time available, a fireline with a sufficient margin of safety to hold the fire within the limits planned. Since rate of line construction depends to a large extent upon the kind of line being built, the construction of a higher standard line than is needed to hold any segment of the fire is rarely warranted. Under certain conditions the use of firelines as transportation ways over which to service suppression forces will influence the required specifications.

Backfiring has been used for many years with varying success as an important method of increasing the effectiveness of control lines as barriers and of decreasing the duration of the patrol job. Experience has indicated that it has a profitable place in fire control and that by its judicious use much can be gained not only in ease of suppression but in total area burned. The proper use of backfiring under the variety of conditions encountered in fire suppression requires, however, a detailed knowledge of many fire behavior characteristics and of the variables which influence them. Its planned use, moreover, should hinge upon prediction of the conditions which will assure success at the time the backfiring is to be done. Further improvement in knowledge of the ways fire will react to given conditions, and in ability to predict the conditions is badly needed to strengthen backfiring practices.

In fire suppression, proper timing of operations is of great importance with reference to action of the fire, to diurnal trends of weather, and to completion of other operations. Usually, the time available is short so that every possible scheme must be employed for increasing the total suppression output of men and equipment on hand for the job.

Although line construction, backfiring, holding, and mopping-up, are normally accomplished in the order named, conditions may possibly be encountered on the line which might make for more efficient action if the order were changed. For example, heavy fuels inside the line might, under certain conditions, better be cleaned up before backfiring.

Rapid advances have been made during the past decade in the use of tank trucks and power equipment for line building. Under some conditions tank trucks might be employed to advantage in all the recognized line operations on accessible parts of the fire. Tank trucks vary in kind and size, so the planning job must recognize the limitations and advantages of each in order to assure their most efficient use under any given set of conditions. The same requirement is true of the planned use of power line-building equipment. But, here, efficient suppression action requires as well, a knowledge of line production rates by different kinds of equipment in order that a balance between equipment and manpower requirements and distribution may be planned and maintained.

SUPPRESSION - STRATEGY AND TACTICS

Success of the plan of attack on a fire depends to a large extent upon ability to calculate rapidly probable fire behavior and production rates of men and equipment. The need for additional and more accurate aids to this planning process is generally recognized. Further development of weather measuring and predicting instruments, fire behavior meters, production tables, and other devices offer possibilities toward better suppression planning.

QUESTIONS	STATUS
a. Where should fire lines be located with reference to all those factors which influence their efficiency and ease of construction and holding?	Approved practices specified in handbooks. Still more information is needed.
b. On what should line specifications depend and how do the factors influence the specifications?	Do
c. What factors should govern the selection of backfiring as a strategic measure?	Some, but not all of controlling factors known. Better methods of integrating their effects are needed.
d. What conditions should establish the order of working different parts of the fireline within each control unit?	Some approved practices for typical situations.
e. What conditions should establish the order in which the different fireline operations are carried out to yield maximum suppression efficiency?	Generally follow set pattern. Possible gains through variation should be studied.
f. Where should tankers of different sizes be used in fire suppression?	General information available. Special study desirable.
g. What determines the distribution of large and small power line-building equipment on the fire?	Available information derived from experience. Need better methods for getting application of knowledge.
h. What instruments and devices can be used to advantage for tactical purposes on the fireline?	Uses of some aids prescribed in handbooks but application is sporadic. Better techniques are needed.
i. When are desperation tactics in fire suppression warranted? Of what do they consist?	Requires study. Present policies are not sufficiently established, although some problems have been covered in the Region 5 Fire Control Handbook, Volume III.

Problem 52.

THE BEST METHODS FOR ACCOMPLISHING THE PHYSICAL JOBS OF LOCATING AND CONSTRUCTING FIRE LINES

Fire suppression execution involves the physical task of carrying out the necessary line jobs in accordance with planned strategy and tactics. The problems that arise require for their solution a mass of production, management, and fire behavior knowledge. Many of the problems are closely associated with those encountered in planning strategy and tactics. In both cases the available information is mostly general and in need of refinement.

One of the first tasks confronting the suppression crews is to get the line location actually marked on the ground so that construction may proceed. Much time and labor can be lost by poor line location or unsatisfactory marking.

A choice must also be made of the method of line construction, depending upon such factors as type of fuel, topography, behavior of the fire, experience of men, and the time allowed for completion of the job.

Should conditions permit, additional time for line construction may be obtained by utilizing auxiliary means, such as buffer lines, to delay the approach of the fire to the chosen line position.

QUESTIONS	STATUS
a. How can best line location be most readily established on the job?	A number of methods are available and in local use. Problem needs general analysis with provision for systematic application of results.
b. How should the method of line construction be determined?	Do
c. How can fire be temporarily checked to gain time for line construction and when should this be done?	Different methods are in limited use locally. Definition needed of time and effort warranted in temporary lines.

Problem 53.

BEST METHODS FOR SECURING GREATEST MANPOWER EFFICIENCY IN "ON-THE-LINE" JOBS

Because speed is so necessary to effective suppression the factors governing crew output are of considerable importance and an understanding of them is obviously essential to the greatest suppression efficiency. Such things as heat, humidity, fatigue, topography, and length of shift are known to affect output per man. Others, such as crew size, type of labor, method of working, efficiency of overhead, hours of shift, and the order of doing line jobs, undoubtedly have important bearings on output, and knowledge of their influences should be fully utilized to increase suppression efficiency. Increased knowledge, together with its intensive application on the ground, may provide the answer.

QUESTIONS	STATUS
a. How can more men be gotten to work more effectively more of the time?	A large management problem. Warrants detailed consideration.
b. On what does work output of line crew depend?	Few data available. Problem needs special study.
c. What is the effect of crew size, fatigue, and other pertinent factors?	Some preliminary work in Region 6. No data in California. Problem needs intensive study.
d. On what should the method of functioning of crews depend?	Few data available. Problem needs special study.
e. How does crew efficiency vary with overhead efficiency?	Do.
f. How should work shifts be distributed through a 24-hour day?	More or less standardized. Study of possible benefits of other arrangements desirable.
g. How can rates of line construction be improved?	Special study needed.

Problem 54.

THE HAND AND POWER EQUIPMENT BEST SUITED TO THE DIFFERENT LINE OPERATIONS AND THE BEST TECHNIQUES OF USE

Maximum rates of line construction by hand labor can be secured only when the crews are equipped with tools suited to the men and to the job. The present trend is to mechanical line builders whenever available and wherever conditions make their use possible. This trend normally results in the assignment of hand crews to the rougher, more difficult portions of the line where the selection of proper tools may have critical importance. In the case of both hand and power tools, the possibility of increasing production rates by improving techniques of use is evident. The problem of maintaining proper balance between manpower and equipment is becoming a rapidly increasing one.

QUESTIONS	STATUS
a. What conditions determine the selection of different kinds of hand tools used on fireline jobs?	Largely decided by man in charge on the basis of experience. Special study needed.
b. What conditions determine the selection of mechanical fireline builders and hand methods?	Do.
c. What rates of line construction can be expected from power line-builders?	Line-builders widely used, but there is little information on the effect of size of machine, cover type, and topography on the rate of production.
d. What are the best techniques of using various types of hand equipment?	Largely traditional. Much opportunity for improvement.
e. What are the best techniques of using various types of power equipment?	Do.
f. What are the best techniques for applying water and chemicals in suppressing a fire?	Present practices are being improved but much still remains unknown.
g. What is the best balance between mechanical line building equipment and manpower in different cover types?	Present tendency is to over-man most fires on which power equipment is used. Additional study is badly needed.

Problem 55.

SAFETY PRINCIPLES, PRACTICES, AND EQUIPMENT BEST SUITED TO REQUIREMENTS OF THE SUPPRESSION JOB

A good portion of the physical output to be expected from men on the line depends on their physical and mental condition when they start work. This in turn depends on such things as original condition, treatment in camp, and energy expended in getting to the job. After arrival of men on the line, sufficient food and water, and proper protection from smoke, sparks, heat, and falling and rolling materials are required to maintain their morale and stamina.

QUESTION	STATUS
a. What measures can be taken to insure the safety of men on the fire line?	General information available. Problem is mostly in getting it used.

Problem 56.

DEVELOPMENT OF THE BEST PRINCIPLES, PRACTICES, AND EQUIPMENT FOR THE BACK FIRING JOB

After constructing an adequate line, the next operation, normally, is to backfire. Backfiring is not only a delicate, but a dangerous operation, demanding discrimination and a complete understanding of the conditions governing its action. It is frequently affected by the behavior of the main fire and is often set so as to take advantage of drafts created by the main fire. Many tools and techniques are available, all of which will bear scrutiny and improvement in view of the need for speed and sureness in this operation.

QUESTIONS	STATUS
a. What precautions should be observed in backfiring?	Existing practices developed through experience. Need additional indicators to determine need of precautions.
b. How can conditions favorable to backfiring be identified?	Information general, - should be more specific.
c. How can backfiring best be associated with the behavior of the main fire?	Little information available. Important problem is that backfiring should frequently be governed by behavior of main fire.
d. What tools are best suited to backfiring?	Development needed.
e. How can the techniques of backfiring be improved?	Requires and warrants detailed study.

Problem 57.

THE BEST TECHNIQUES FOR LINE HOLDING

Problem 58.

THE BEST TECHNIQUES FOR PATROL AND MOP-UP

In the line jobs of holding, patrol, and mop-up, as in the preceeding operations, there are many diverse practices which have been evolved through long experience. Many have stood the test of time, and are found approved in fire control handbooks. However, the techniques, tools, and governing conditions need reexamination particularly from the standpoints of increasing the work output of individuals and of insuring constant coverage of dangerous line.

QUESTIONS	STATUS
a. How can the techniques of line holding be improved?	Approved practices exist. Possibility of further development.
b. What are the relative advantages of water, chemicals and dirt in line holding?	Little information available.
c. What conditions should control the spacing of patrolmen?	Approved practices can probably be improved.
d. What conditions should govern the action of patrolmen?	Do.
e. How can mop-up practices be improved?	Requires study of existing practices and their shortcomings.
f. What are the relative advantages of water and chemicals in mop-up?	Little information available.
g. What causes controlled fires to get away?	Requires special analysis.

Problem 59.

THE BEST FIRE FIGHTING TECHNIQUES FOR HANDLING SPOTTING, CROWNING, AND FINGERING

In spite of the best of planning and execution, breaks are bound to occur. It is important that such cases be examined closely for lessons which will enable other firefighters to avoid the same misfortunes. Various things that the fires may do, such as crown, spot, or finger, have important bearings on the actual execution of planned strategy and, where unexpected, they may necessitate modification of the tactics, or in any event require special defense measures over and above the regular line construction job.

QUESTIONS	STATUS
a. What can be done in fire suppression to take care of actual or anticipated spotting?	Additional knowledge of governing conditions is needed. Improvement in present methods is probably desirable.
b. What can be done in fire suppression to take care of actual or anticipated crowning?	Do.
c. What methods of attack are best suited to control fingers of a fire?	Do.

Problem 60.

THE BEST METHODS FOR GATHERING AND DISSEMINATING NEEDED INFORMATION ON BEHAVIOR OF THE FIRE AND PROGRESS OF CONTROL OPERATIONS

Even with the most efficient suppression management the operation may still extend over a long enough time to encompass radical changes in the conditions governing fire action. It is of the utmost importance that the fire boss keep in close touch with the actions of the fire and the progress of control operations to be sure that both are proceeding as anticipated. Scouting can be made to contribute in a major way to efficient suppression of large fires if properly organized and executed.

QUESTIONS	STATUS
a. What information must a fire boss have to enable him to do a good job in suppressing a fire?	Requires more thorough job analysis.
b. How can essential information best be gathered?	Existing practices may be improved.
c. How can essential information best be made available?	Do.

Problem 61.

THE BEST METHODS FOR DETERMINING NEEDED STRENGTH AND DURATION OF MANNING A FIRE FOLLOWING CONTROL

There is much need for ability to recognize the conditions which will permit reduction in the strength of manning of a fire, or of a major portion of it, without jeopardizing the success of the control job. When a fire is under control it is advisable to scale down forces as rapidly as is consistent with safety in order to save on suppression costs. Present practices too frequently result either in losing the fire through too rapid demobilization or in excessive suppression costs through unnecessary delay in reducing forces.

QUESTION	STATUS
a. What should govern the strength and duration of manning a fire following control?	Largely done on basis of experience and judgment. More exact guides might be developed.

Problem 62.

THE BEST METHODS FOR PREDICTING THOSE FIRE BEHAVIOR PHENOMENA SUCH AS RATE OF SPREAD, CROWNING, SPOTTING, AND FINGERING, WHICH INFLUENCE THE SUPPRESSION JOB

A major part of the fire suppression executive's job is not only to know what the fire is doing, but to predict with adequate reliability what it will do during the control interval and how it will react to particular control measures. The knowledge he may have on these points will influence the strategy, tactics, and all other phases of planning the suppression job, Accordingly, the importance of sound factual knowledge of fire behavior cannot be over-emphasized.

QUESTIONS	STATUS
a. In what ways do fires behave that must be considered in fire suppression?	Generally known from past experience. Relationship of behavior phenomena to suppression measures needs review.
b. In terms of what units should fire behavior phenomena, such as rate of spread, crowning, spotting, and fingering, be evaluated for suppression purposes?	Comparatively little exact information available. Answers being sought by current fire behavior research.
c. To what degree of accuracy should fire behavior phenomena be estimated or predicted to serve adequately fire suppression needs?	Measurement units need standardization.
d. What must be known to predict the occurrence and intensity of the fire behavior phenomena which influence planning and execution of the suppression job?	Do.
e. What is the specific relationship between each behavior phenomenon and its controlling independent variables?	Do.
f. How can the independent variables controlling fire behavior be estimated or measured in the field to serve fire suppression needs?	Do.
g. How do variations or discontinuities in the variables controlling fire behavior phenomena influence the general behavior of large fires?	Do.

QUESTIONS	STATUS
h. How do large fires influence local weather which in turn may influence fire behavior?	Do.

Problem 63.

THE STRUCTURE AND MANAGEMENT OF THE OVERHEAD ORGANIZATION WHICH WILL MEET THE SUPPRESSION NEEDS OF LARGE FIRES MOST EFFICIENTLY

The problem of overhead organization and management is ever present on large fires. Full authority and responsibility for all suppression action has always been delegated to the fire boss. These large fires, however, require the planning and execution of innumerable details far beyond the capacity of one individual. Consequently the fire boss is confronted with the problem of setting up some form of organization and delegating to individuals specific responsibilities.

In the suppression of a fire, there are two generally recognized overhead functions: (1) planning and supervising the fireline job; and (2) coordinating all operations and directing the behind-the-line activities.

At present, the structure of the line overhead organization is reasonably well standardized, and the functions and responsibilities of different jobs are fairly well established. Structure of the behind-the-line organization is controversial, and questions have been raised as to whether all possible resources should be devoted to the line operations with a minimum organization behind-the-line to perform essential services, or whether there should be a strong behind-the-line organization not only to provide service, but to coordinate all operations on the whole fire. The problem might be considered as one of centralized versus decentralized suppression management.

Another important problem of organization is that of varying size and structure of the suppression force to meet the changing needs of the suppression job. Flexibility, permitting rapid break-down as well as rapid build-up, is needed to meet the demand for reduced suppression costs.

QUESTIONS	STATUS
a. How should size of the suppression job influence structure of the overhead organization?	Structure does not usually follow a uniform pattern of growth as the size of the job increases. Job load analyses and better mechanics of organizing needed.
b. How does the planned strategy influence the overhead organization?	Strategy is now employed in determining organization needed. Reanalysis of the overhead problem is needed.
c. What principles of personnel management should determine the type of suppression organization?	At present generally guided by experience of individual fire boss as well as by established approved practices.

SUPPRESSION - OVERHEAD ORGANIZATION

QUESTIONS	STATUS
d. What organizational structure is best suited to the fire suppression job?	Some studies have been made. More are needed.
e. What are the best mechanics in organizing suppression forces on the fire?	Do.
f. How does overhead efficiency vary with length of shifts?	Requires special study for conclusive evidence on which to base policy.
g. Is there a place for organized overhead teams in large fire suppression?	Some studies have been made but results are not conclusive. Used to considerable extent in R-6.
h. How should balance be obtained in the distribution of manpower and equipment to different fire suppression jobs?	Done now on the basis of experience. More exact methods would require special study.
i. What are the minimum specifications for personnel to fill individual overhead jobs?	More detailed information desirable.
j. What governs the accountability for success or failure of fire suppression action?	Usually governed by broad administrative policy adjusted to local needs. Reanalysis would be desirable.
k. Who should determine the strategy in suppression of a fire?	Detailed study needed to take advantage of much accumulated experience.
l. What measures would assure that proven practices be utilized in carrying out the suppression job?	Many large fires still result from failure to utilize fully proven practices. Study in management is needed.
m. What can be done to relieve the fire boss of excessive physical and mental strain?	Present tendency is for fire boss to assume great overload of responsibility and physical work.
n. Can the fire boss function to best advantage in camp or on the line?	Requires more information and analysis of individual experience.
o. Where should fire headquarters be located?	Merits of the possible choices need consideration. Transportation and communication equipment development have changed the picture during recent years.

QUESTIONS	STATUS
p. What should be the function of inspection in fire suppression operations?	Appears to need more attention. Not frequently employed except as an incidental function.

Problem 64.

THE BEST PRINCIPLES AND METHODS OF CAMP MANAGEMENT TO INSURE MAXIMUM NUMBERS AND EFFICIENCY OF MEN ON THE FIRE LINE

The forces on the fireline must be well equipped and physically able to work at peak productivity. The function of service is to supply all necessary equipment, rations, aids, and conveniences to the line forces when and where needed. Problems thus arise as to what services are necessary and how such services can best be provided.

Fire camps have always been considered the centers of servicing activity in fire suppression. During the past decade there have been many innovations designed to make them better adapted for this purpose. This progress has been largely in equipment development, however, with no striking alterations in the older methods of management, except possibly the dropping of prepared meals from airplanes to crews on the line. There has been some recent emphasis placed upon making organized crews into self-sufficient units requiring little or no camp servicing. This innovation, too, warrants further study.

QUESTIONS	STATUS
a. How can manpower on fires be conserved?	Further work on this subject is desirable.
b. What is the best diet for a fire-fighter?	Needs systematic study.
c. What controls over men in camp are most conducive to efficient operation of the suppression job?	Much has been done but further improvement is possible, particularly in methods of exercising the control.
d. What minimum comforts and rest are consistent with efficient fire suppression?	Requires special study.
e. What measures can be taken to provide comfort to men in camp?	Do.
f. What are good morale builders for use on fires?	Do.
g. What measures can be taken to insure the servicing of men on the fire line?	Recent measures include servicing by airplanes. Additional study needed.

SUPPRESSION - SERVICE OF PERSONNEL AND EQUIPMENT

QUESTIONS	STATUS
h. What are the minimum camp equipment requirements for an n-man crew?	Fairly well standardized but improvement no doubt possible.
i. What fire camp layout and management is best suited to servicing men and equipment?	Principles fairly well standardized. Some improvement could be made in adaptations to ground conditions.
j. How should fire camp locations be selected and what factors govern?	Guided by experience. Further study might be profitable.
k. What are the relative advantages of fixed and mobile fire camps?	Special study warranted.
l. How can procurement of subsistence supplies be expedited and reduced in cost?	Present practices good. Room for improvement.
m. What can be done to insure the best diet and economy in feeding?	Requires special study.

Problem 65.

THE BEST METHODS FOR HANDLING AND SERVICING FIRE FIGHTING TOOLS AND EQUIPMENT ON GOING FIRES

To keep tools and other facilities serviceable there should be frequent inspection and servicing of the equipment in use on the line. On large fires the task is tremendous and presents a major problem. Critical study and improvement of present methods is needed.

Rapid expansion in the use of motorized suppression equipment in recent years has introduced another important equipment servicing job in need of review and improvement at the present time.

QUESTIONS	STATUS
a. How can fire equipment losses be reduced?	Systems of checking usually employed but further advances can be made.
b. How can handling and servicing of hand tools and small equipment be improved?	Needs special study.
c. What services are needed on the fire for mechanical equipment and how can those services be administered most efficiently?	A relatively recent need that requires more attention.

Problem 66.

ECONOMICAL AND EXPEDITIOUS TRANSPORTATION OF MEN, EQUIPMENT AND SUPPLIES ON FIRES

Difficulties encountered in transporting men and equipment on the suppression job frequently lead to confusion, to failure to accomplish specific suppression objectives, and to excessive losses in time for rest and work on the line. The present systems of transportation, particularly by truck, airplane, and by pack stock, are in need of intensive improvement and correlation.

QUESTION	STATUS
a. How can transportation of men and equipment on the fire be speeded up and at the same time reduced in cost.	Requires special and detailed study.

Problem 67.

THE BEST WAYS TO ORGANIZE AND OPERATE NEEDED SUPPRESSION COMMUNICATION FACILITIES

Communication systems especially adapted to the needs of fire suppression have resulted from increased general use of portable radio equipment. As more and better equipment becomes available, it is reasonable to assume that radio will be used more and more on going fires. This in turn will put additional emphasis on the problem of organizing and managing the net work needed to meet the communication requirements of each individual fire.

QUESTIONS	STATUS
a. What communication facilities are essential to efficient conduct of the suppression job?	Requires reanalysis in terms of present available equipment.
b. How can communication facilities be organized and operated to serve adequately all the needs for communication on a fire?	Requires reanalysis in terms of present available equipment. Preliminary work in organization of the available facilities has been locally successful.

Problem 68.

THE NECESSARY FIRE RECORDS AND THE BEST METHODS FOR OBTAINING AND RECORDING THE REQUIRED INFORMATION

The need is generally recognized for more accurate and complete records of manpower and equipment performance, of fire behavior, and of those variables on which both manpower and equipment performance and fire behavior depend. Nearly all presuppression and suppression planning now depends for information on a heterogeneous composite of past fire history and performance records of varying standards. Better and more complete plans could certainly be made if better and more complete data on each fire were available. Thorough study of these problems is urgently needed.

QUESTIONS	STATUS
a. What purposes can individual fire records serve?	Fairly well worked out. Improvement possible.
b. What records are needed?	Do.
c. How should records be obtained?	Do.
d. When should records be obtained?	Do.
e. Who should obtain and compile records?	Do.
f. What is the relationship between record taking and overhead efficiency?	Requires special study.
g. How should records be compiled?	Systems developed. Further study needed.
h. What are the relative advantages of different timekeeping systems?	Systems commonly in use involve much time and labor. Improvement possible.
i. What can be done to improve record keeping on the fire?	Requires special study.
j. How can better records be obtained?	Do.

EFFECTS

In the case of intense fires that rage through forest or chaparral leaving complete destruction in their wake, the direct damage to the cover is obvious and definitely recognized. Less obvious, often unrecognized and unmeasured, are the damaging effects to timber, reproduction, soil, site, wildlife, watersheds, recreation, and other values. In many parts of California, where most fires run through the ground cover and litter comparatively lightly, there is relatively little damage apparent after any one fire. Yet, the gradual cumulative effects of these light fires have resulted in thousands of acres of waste lands and underproductive brush-fields in this state, isolated patches of mature timber inaccessible to logging, change in forest type to less valuable species, depreciation of scenic values, increase in costs and difficulties of fire protection, and disastrous floods and silting of agricultural lands with loss of soil and irrigation waters.

On the other hand, it may be that certain benefits may possibly accrue from fire under some circumstances, although these have never been definitely established, and that fire under control might be made a useful agent in clearing the forest of slash, snags, ground litter, and underbrush, in reducing the fire hazard of chaparral and inflammable annual vegetation, in improving forage, and even in aiding reproduction, if the detrimental effects are not found to be too great.

A knowledge of the detailed effects of forest fires is important from several standpoints. First, it is needed to justify an intensity of protection commensurate with the benefits derived or the damages avoided. Second, the information is needed for use in fire prevention propaganda. Third, data are needed for damage appraisals that will be valid in court. Fourth, it is imperative that the damages and benefits of fires on different kinds of areas and under different burning conditions become known so that controlled fire may take its proper place as a land management tool. Determination of fire effects will lead toward the ultimate establishment of protection systems and policies based upon demonstrable facts. Only through a knowledge of fire effects can the economics of fire protection be understood.

Problem 69.

SATISFACTORY METHODS FOR ESTIMATING FOREST VALUES

Appraisal of the effects of a forest fire is complicated by the diversity of forest values and the lack of appraisal methods for any but the simplest ones. Not only are we unprepared to estimate completely the worth of forest values on a given area but we are equally unprepared to appraise the effects of a fire running through such values.

QUESTIONS	STATUS
a. What values and resources should appraisal of fire effects include?	The more significant items have been recognized at one time or another. Satisfactory methods of estimating all the various values are not available, nor are there reasonably exact methods of combination.
b. How can the values of forest resources be measured and expressed?	

Problem 70.

THE BEST METHODS FOR MEASURING AND ESTIMATING THE DETRIMENTAL AND BENEFICIAL EFFECTS OF FIRES WHICH HAVE OCCURRED, AND OF PREDICTING THE PROBABLE EFFECTS FROM FIRES WHICH MAY BE EXPECTED TO OCCUR UNDER DIFFERENT BURNING CONDITIONS

Almost every fire will have some bad effects and some good, the relative extent being determined by such things as intensity of the fire and values on the area before the fire. In general the net effect of fire is probably detrimental to forest use and production. More rarely the effects may be beneficial as in aiding natural reproduction, in clearing off slash, snags, ground litter, and underbrush, and in improving forage. Although the ill effects of burning are usually outstanding, it may be that in certain instances the benefits derived exceed the damage and it is important to recognize the conditions upon which the ultimate good or bad predominates.

Damage to timber, reproduction, forage, and improvements may be quite readily measured and expressed in terms of dollars. The indirect effects, such as deterioration or improvement of the site, erosion, and loss of water storage capacity are more difficult to appraise; yet, their values may exceed those of more easily ascertainable character. Satisfactory evaluation of fire effects necessitates consideration of all resources, including dependent values, as well as a complete summation of all losses and gains into a grand total.

Not only is it important to be able to measure fire effects, but also it is necessary to recognize the variables which determine the magnitude of the effects and to understand how these variables exert their influences. These variables are numerous, involving weather, topography, fuel, cover, soil, species, values at stake, frequency of burning, and many others. Nevertheless, only by a complete understanding of their combined influences can fire damage be predicted under different conditions, or can conditions be intelligently altered so as to lessen the possible magnitude of fire damage.

It is reasonable to assume that fire damage increases with fire intensity but precisely what the relation is, is unknown. To classify forest fires according to intensity would seem to be a convenient intermediate step in relating independent variables to fire damage. An understanding of what factors govern fire intensity and how they operate would permit prediction of possible damage prior to a fire, and point out the need for and means of controlling those conditions particularly conducive to excessive damage.

Moreover, the effects of fire are never all apparent immediately after a fire but are gradually accumulative year after year from subsequent delayed mortality and from attack by insects and fungi of fire-injured trees. Fire intensity, however, should be measurable during or immediately after a fire. If from previous research the relation between fire intensity and fire damage were known, the latter could at once be estimated.

EFFECTS

Fire effect appraisal is only in the incipient stages of progressive development. A wholly complete and satisfactory system of evaluation of all the fire effects should not be expected soon. Nevertheless, for purposes of public education, legislation, protection financing and insurance, there is immediate need for some fairly trustworthy method of estimating certain effects such as the fire damage to forest trees. Thus, if too great a degree of refinement is not required, fixed values might, from present knowledge, be assigned to damage of stands of different types, age classes, and conditions which would provide the administrator means of getting comparable estimates over a large territory.

QUESTIONS	STATUS
a. What damage may forest fires do?	The more significant items are recognized. Definitions and methods of measurement are badly needed.
b. What beneficial effects may result from fire?	Benefits that may result from fire have never been well demonstrated in California.
c. What are the conditions which determine how beneficial or detrimental a fire has been or will be?	Some general information available. More definite information is needed.
d. How should the conditions which determine how beneficial or detrimental a fire is be evaluated and integrated?	The more significant items are recognized or have been recognized at one time or another. Satisfactory methods of estimating certain values are not available, nor are there reasonably exact methods of combination.
e. How should the various individual fire effects items be evaluated and expressed?	Do
f. How should the items of fire effects be integrated?	Do
g. What factors govern the magnitude of the various fire effects?	Requires special study for California cover types. Early damage studies in California, while indicating the form and extent of damage to timber, did not cover entire field nor relate damage to specific contributing factors.
h. How can the cumulative effects of repeated burning be evaluated and integrated?	Do
i. How do the individual fire effects vary with repeated burning?	No specific information available.

QUESTIONS	STATUS
j. What is the relation between fire intensity and fire effects?	Some general information available. Intensive study needed.
k. How can fire intensity be evaluated?	Do
l. What factors govern fire intensity and how do these factors operate?	Do
m. What cultural steps can be taken to reduce possible fire damage?	Past attention mostly confined to slash disposal following logging and to light burning. More study needed.
n. How do fires influence the losses incurred from fungi and insects?	Only the most general kind of information available. Data needed.
o. When should fire effects be appraised?	General practice is to appraise soon after fire is controlled. Additional data required.
p. How can fire effects be appraised more satisfactorily with present knowledge?	Study badly needed.
q. How can fire damage at present be more completely evaluated and reported for the purposes of education, law enforcement, legislation, protection financing, and insurance?	Do
r. To what degree of refinement should individual fire effects be evaluated?	Would require administrative decision based on further study of effects.

Problem 71.

THE PLACE OF CONTROLLED BURNING IN THE MANAGEMENT OF THE FOREST AND RANGE LANDS OF CALIFORNIA

The present status of controlled burning in California is wholly unsatisfactory. Factual information is essential to justification for present protection agencies policies or to revision of these policies where increased public benefits may result. Much of the damage caused by fire in the forest is obscure, and this very obscurity is responsible for the widespread belief that light burning does no damage. Only prolonged investigation can give a true measure of the extent of both beneficial and harmful effects as well as a correct understanding of the conditions under which controlled burning can be done to achieve benefits without serious harm.

QUESTIONS	STATUS
a. Under what conditions can controlled burning be done with safety and economy?	Information available is based on experience alone. No relation to fire danger measures has been attempted in California.
b. What techniques of controlled burning are most practical from the standpoint of safety and economy?	Information available based on individual experience does not answer the whole problem. Additional study is needed.
c. Where and when should controlled burning be employed in the management of wild lands in California?	Now practiced rather indiscriminately on range lands with much conflict between operators and protection agencies. A high priority problem, particularly concerning State and County protection administration.

ECONOMICS

The ultimate objective of forest management is to obtain the full social benefits of the forest and its products with the least cost. To minimize economic and social losses to the public, the necessity for prevention or control of forest fire is fast becoming universally recognized.

But fire control expenditures must be economically commensurate with benefits derived by protection from fire - benefits to the lumber industry, to reproduction, to watersheds, to wildlife, to recreation and scenic values, to local populations, and to the numerous other forest users and usages. The optimum intensity of fire protection to be given any area depends upon the purposes of the management of that particular area, the objectives of each forest management purpose, the values to be protected, and the expense of maintaining the requisite fire protection organization.

Fire protection cost may be reduced not only by perfection of organizations and techniques, but also by a judicious distribution of expenditures, by competent cooperation between different agencies, by agreeable and equitable legislation and prudent enforcement, and by land use well considered from the standpoint of fire protection needs. Such courses of action bring about efficiency in securing maximum accomplishments at minimum cost, and at the same time are conducive to general public confidence and civicism.

These are economic problems. They must be solved to overcome the difficulties confronting intelligent land management of both public and private forests and to make forest land take its proper place in our economic and social system. The forest economic investigation that will be required to solve these problems is necessarily a most important class of research.

Problem 72.

THE PROPER EXPENDITURES FOR FIRE PROTECTION IN RELATION TO DEMONSTRABLE BENEFITS

The justifiable cost of fire protection depends on the benefits to be derived from that protection. Thus, if timber production is the object of management, fire control expenditures must be great enough, but only great enough, to insure that yield essential to the management will not be interrupted. On areas principally important as watersheds, expenditures must be adequate to safeguard the dependent investments. The degree of protection necessary depends, therefore, upon the purposes of forest management and the possible damage by fire to forest values.

Each forest management purpose must have its particular objective, probably in terms of the maximum allowable burn under which a sustained yield of forest productivity is possible. The adequacy of the organization will be measured by how well these objectives are met. The cost of the fire protection organization, therefore, hinges directly upon the fire control objectives. The importance is obvious then of the necessity for specified objectives which are to serve as an economic basis for financing fire control activity and for distributing finances between protection units.

QUESTIONS	STATUS
a. What should be the ratio between cost of protection and value of benefits on public forest?	The benefits derived by having an adequate fire control system are based primarily on the possible damage. Damage appraisal to all forest values is not yet satisfactory.
b. How can the ratio between cost of protection and value of benefits be determined?	Do.
c. What ratio between cost of protection and value of benefits results in minimum total cost?	Has not been established.
d. How can the adequacy or inadequacy of fire control expenditures be determined?	During the past decade various kinds of investigations and studies have been made to determine both the needs and cost of an adequate fire control system.
e. How should the cost be calculated for an adequate fire control system to meet certain objectives?	Revisions are being made continuously as better data become available.

QUESTIONS	STATUS
f. On what basis should fire control expenditures be distributed between protection units with differences in intensity of fire problem?	Inherent protection unit differences as to fire damage are recognized, but no strictly logical basis for distributing fire control expenditures between the units has been advanced.
g. How does the interrelation of costs of prevention, presuppression, and suppression influence cost of protection?	Little on this subject is known. Special study required.
h. How should the distribution of expenditures between prevention, presuppression, and suppression be determined for specific objectives?	Do.
i. What increases in fire protection are required and justified on planted areas?	Some added protection given now, whether to proper extent is not known.
j. What part should the need for fire protection of marginal lands and adjacent areas play in the marginal land management?	Need for improved protection is recognized. The place of protection in the program is not well defined.

Problem 73.

THE PUBLIC VALUES AT STAKE ON PRIVATE LANDS AND THEIR WORTH TO THE PUBLIC TO PROTECT THEM

In California there is nearly twice as much private as public forest and watershed land needing fire protection. Because of public values at stake on the private lands, their protection too, has been recognized as being largely a public function. The extent to which public and private ownership should share in fire control costs is an economic problem of importance.

It is a matter of great public concern that our forests be maintained in a productive state, yet there is often considerable conflict between the interests of society as a whole and what individual forest owners conceive to be their own interests. A sound policy of forest conservation must recognize the public's interest in private forests, the public's responsibility for protecting these forests, and the private owner's responsibility to the public.

QUESTIONS	STATUS
a. What are the public values on private lands?	Recognized on farm lands. Forest lands need further consideration.
b. How can these values be given monetary worth?	Little known.
c. What measures should be taken to protect these values?	Pattern established for farm and certain types of forest land. Clarke-McNary Law represents only partial solution.
d. What is the public justified in spending to protect these values?	Do
e. What are the responsibilities of federal, state, and county governments for public values of private lands?	Partially recognized under Clarke-McNary Law. Comprehensive study needed.
f. What is the responsibility of a private owner to the public?	Do

Problem 74.

IMPROVEMENT AND EXTENSION OF FOREST AND FIRE LAWS FOR BETTER AND CHEAPER FIRE PROTECTION

In California, where such a large percentage of the forests are privately owned, a public policy for forest conservation must be built upon regulation of private owners, operators, and other forest users. To serve the public's interests it is desirable to provide some degree of regulation to restrict wanton handling of privately owned forests and other uneconomical forest operations and practices.

QUESTIONS	STATUS
a. What advantages to private owners and fire protection agencies can be expected to accrue from regulation of forest practices?	Needs further study in the light of recent proposals for regulation.
b. How should existing fire laws be amended and extended?	Reconsideration and program needed.

Problem 75.

THE PORTION OF THE SUBSEQUENT INCREASED COST OF PROTECTION THAT LOGGING OPERATORS SHOULD BEAR

Even the best of logging practices leaves the cut-over forest more open and with higher wind velocities, more exposed to sunlight and with drier fuels, with an accumulation of slash, and with a denser understory of lesser vegetation. All these conditions enhance the needs for fire protection following the opening of stands by logging operations. Of importance, therefore, is the question of who should bear the increased cost of fire protection on public and private cut-over lands.

QUESTIONS	STATUS
a. How do different methods of logging influence subsequent costs of protection of the logged areas?	Some information available.
b. What portion of the increased costs of fire protection should logging operators bear?	As yet undetermined.
c. To what extent should logging operators be financially responsible for increased fire threat to adjacent areas?	Do

Problem 76.

EQUITABLE DISTRIBUTION OF COST OF PROTECTION BY FOREST TAX ADJUSTMENTS

Closely allied to the problems of public and private economic responsibility and interests and of apportionment of fire protection costs on logging operators, are the problems of making forest waters and wildlife bear their share of the financial fire protection burden and of levying fees and taxes on all forest users and operators to cover their proportionate fire control costs.

QUESTIONS	STATUS
a. On what basis should cost of fire protection be calculated for purposes of taxation?	Very little information available.
b. What tax adjustments can be made to compensate the private owners for protection of public values?	Study needed to indicate possibilities.
c. What tax adjustments should be made to compensate private owners for increased fire threat by public use of his land?	Do.

Problem 77.

FOREST FIRE INSURANCE FOR PRIVATE FOREST OWNERS

Of particular significance to the private owner is the economic problem of fire insurance. The desirability of such insurance is recognized and it is most important to understand thoroughly the principles involved and the conditions under which the practice would be generally economical.

QUESTIONS	STATUS
a. Under what conditions is forest fire insurance feasible?	Initial study completed in California. Results not applied.
b. How would insurance rates vary with the intensity of fire protection?	Information lacking.
c. How would insurance plus protection costs vary with the expenditures for protection?	Small amount of information available.

Summary of the 77 Fire Protection Problems with Assigned Ratings of Administrative Importance

Problem number	- PREVENTION -	Relative importance	Reference page
1.	The objectives and policies of fire prevention work.	Medium	31
2.	Effectiveness of fire prevention activity and of individual fire prevention measures.	High	33
3.	Susceptibility of different forest fuels to ignition.	Medium	34
4.	Specifications and methods for fireproofing logging slash, right-of-ways, campgrounds, and other forest areas exposed to different kinds of use.	Medium	35
5.	Reduction of forest ignitibility, rate of fire spread, and difficulty of control through modification of silvicultural, logging, and grazing practices.	Low	37
6.	Equipment to meet hazard reduction needs.	Low	37
7.	The relative probability of ignition of forest fuels by different firebrands.	Medium	38
8.	Reduction of probability of ignition of forest fuels through elimination, modification, or control of firebrands.	Medium	39
9.	The risk accompanying different fire causing agencies.	High	39
10.	The prevention measures best suited to counteracting the fire starting habits of forest users.	High	40
11.	Road and right-of-way construction and maintenance specifications to minimize fire occurrence along the right-of-ways.	High	43
12.	Short-term prevention measures best suited to high fire danger resulting from different causes.	High	44

Problem number		Relative importance	Reference page
13.	Relation between ignition probability and the physical conditions of weather, fuel, topography, and use which influence the manner in which fires start.	Medium	45
14.	The conditions under which fire may be used as a management tool without undue risk to adjacent forest areas.	Medium	46
15.	Best method of rating fire danger for use in prevention work.	High	47
	- PRESUPPRESSION -		
16.	Detection standards required to meet varying hour control needs.	Low	49
17.	The best basis for planning primary lookout detection systems.	Low	50
18.	The need for supplementary detection and the best basis for planning an emergency detection system.	Medium	51
19.	Improvement of structures and equipment for increasing the efficiency of lookout detection.	Low	52
20.	The best basis for planning communication systems for forest protection purposes.	Low	53
21.	The best basis for planning a transportation system for forest protection purposes.	Medium	55
22.	The proper role of firebreaks in forest protection and the best basis for planning a firebreak system.	Low	55
23.	The best methods for securing water storage facilities for suppression purposes.	Low	57
24.	Equipment best suited to the different presuppression and fire suppression jobs	High	58
25.	The best system for apportioning fire equipment among different protection units.	Low	59

Problem number		Relative importance	Reference page
26.	The best methods for financing, servicing, and maintaining fire equipment.	Low	59
27.	The best methods for warehousing and packaging fire equipment.	Low	60
28.	The best basis for planning the distribution and strength of manning of fireman stations, including the location and assignment of tank trucks.	High	61
29.	The best balance between intensity of protection and the fluctuating need for protection.	High	63
30.	Reduction in large turn-over in short-term personnel.	Low	64
31.	Maintaining physical fitness and general efficiency of protection personnel.	Medium	65
32.	Training of short-term protection personnel; including appraisal of needs for training, methods of training, and evaluation of the effectiveness of training.	High	66
33.	Training of regular personnel; including evaluation of the needs for training, methods of training, and selection of men for higher training.	High	68
34.	Securing the cooperation which will result in most efficient protection.	Low	70
35.	Development of fire suppression plans as a presuppression activity which will make subsequent fire suppression action most efficient.	Medium	71
36.	The extent to which the protection work of different agencies should be coordinated to secure maximum protection at lowest total cost.	Low	73
37.	Equitable distribution of fire control allotments between protection units.	Medium	73
38.	Securing an efficient balance between the protection activities of prevention, presuppression, and suppression.	High	74

Problem number		Relative importance	Reference page
39.	Securing a balanced presuppression organization.	High	74
40.	The best personnel management methods to get better performance in fire control.	High	75
41.	The manner in which values, their ownership, and their susceptibility to damage affect the intensity of necessary fire protection and the corresponding presuppression activity.	Medium	76
42.	The manner in which probable fire occurrence affects the intensity of necessary fire protection and corresponding presuppression activity.	Medium	77
43.	The manner in which probable rate of spread affects the intensity of necessary fire protection and corresponding presuppression activity.	Medium	78
44.	The manner in which difficulty of control affects the intensity of necessary fire protection and corresponding presuppression activity.	Medium	79
45.	The needs fire danger rating must fill and the best methods of estimating fire danger for these purposes.	High	80
46.	The needs fire records must fill and the best methods for compiling and analyzing the required data.	High	82
47.	Adoption of uniform methods of reporting and compiling forest fire data by the different protection agencies.	Medium	83

Problem number	- SUPPRESSION -	Relative importance	Reference page
48.	The fire suppression objectives and policies.	High	85
49.	The best methods for mobilizing and dispatching manpower and equipment for fire suppression.	Low	86
50.	Methods for predicting and integrating fire behavior and suppression accomplishment information necessary to proper planning of fire strategy.	High	88
51.	Providing information and data necessary for planning the detailed tactical operations required to carry out the suppression job.	High	90
52.	The best methods for accomplishing the physical jobs of locating and constructing firelines.	High	92
53.	The best methods for securing greatest manpower efficiency in "on-the-line" jobs.	High	93
54.	The hand and power equipment best suited to the different line operations and the best techniques of use.	High	94
55.	Safety principles, practices, and equipment best suited to requirements of the suppression job.	Low	95
56.	Development of the best principles, practices, and equipment for the backfiring job.	High	96
57.	The best techniques for line holding.	Low	97
58.	The best techniques for patrol and mop-up.	Low	97
59.	The best fire fighting techniques for handling spotting, crowning, and fingering.	Medium	98
60.	The best methods for gathering and disseminating needed information on behavior of fires and progress of control operations.	High	99

SUPPRESSION

Problem number		Relative importance	Reference page
61.	The best methods for determining needed strength and duration of manning a fire following control.	Medium	99
62.	The best methods for predicting those fire behavior phenomena such as rate of spread, crowning, spotting, and fingering which influence the suppression job.	High	100
63.	The structure and management of the overhead organization which will meet the suppression needs of large fires most efficiently.	Medium	102
64.	The best principles and methods of camp management to insure maximum numbers and efficiency of men on the fireline.	Medium	105
65.	The best methods for handling and servicing fire fighting tools and equipment on going fires.	Low	107
66.	Economical and expeditious transportation of men, equipment and supplies on fires.	Low	107
67.	The best ways to organize and operate needed suppression communication facilities.	High	108
68.	The necessary fire records and the best methods for obtaining and recording the required information.	High	109

Problem number	- EFFECTS -	Relative importance	Reference page
69.	Satisfactory methods for estimating forest values.	High	111
70.	The best methods for measuring and estimating the detrimental and beneficial effects of fires which have occurred, and of predicting the probable effects from fires which may be expected to occur under different burning conditions.	High	112
71.	The place of controlled burning in the management of the forest and range lands of California.	High	115
	- ECONOMICS -		
72.	The proper expenditures for fire protection in relation to demonstrable benefits.	High	117
73.	The public values at stake on private lands and their worth to the public to protect them.	High	119
74.	Improvement and extension of forest and fire laws for better and cheaper fire protection.	Medium	120
75.	The portion of the subsequent increased cost of protection that logging operators should bear.	Low	120
76.	Equitable distribution of cost of protection by forest tax adjustments.	Medium	121
77.	Forest fire insurance for private forest owners.	Medium	121

Distribution of the 77 Fire Protection Problems into Three Classes of Relative Importance

Importance	Prevention	Presuppression	Suppression	Effects	Economics
High	2 9 10 11 12 15	24 28 29 32 33 38 39 40 45 46	48 50 51 52 53 54 56 60 62 67 68	69 70 71	72 73
Medium	1 3 4 7 8 13 14	18 21 31 35 37 41 42 43 44 47	59 61 63 64		74 76 77
Low	5 6	16 17 19 20 22 23 25 26 27 30 34 36	49 55 57 58 65 66		75

SECTION V

FIRE PROTECTION RESEARCH WORK PROJECT

Objectives and Policies

The function of forest fire protection research in California is to aid forest administrators solve fire control problems by securing basic information and by suggesting practical applications of the results obtained. Recognized means of obtaining information in the field of fire protection are through applied research and detailed analysis of past fire history and control accomplishment records. Close association with forest administrators, limited participation in protection activities, and detailed analysis of specific problems provide the basis upon which practical applications of study results may be suggested. The decision to modify fire control practice in the light of new or better information and the manner in which these modifications are executed are, of course, within the sole jurisdiction of forest administration. Because of the tremendous scope of the field and the immediate need for development in many directions, there is recognized the need for both concerted cooperation and a division of labor between research and administration in the attack on high priority problems. Cooperative effort in the solution of some and independent study in others will continue as in the past.

The success of any long-term fire research program in California must be measured, first, by the extent to which the program contributes to better fire control methods and practices within the region, and second, by the extent to which it contributes basic knowledge of broad application and value for the general advancement of fire control practice on a national scale. Thus the selection of problems for the long-term fire research program of the California Station and the manner of their attack will be guided by the following principles:

1. The importance of the solutions of the problems to California forest protection administration will be the chief consideration in establishing research priority.

2. Studies of individual problems will be aimed toward solutions in terms applicable to California conditions.

3. Fundamental research required for solution of practical administrative problems will be conducted in sufficient detail to insure broad, general, and permanent application of the principles and methods evolved.

While the objective of a long-term research program is the solution of major problems through the orderly conduct of uninterrupted research, consideration must also be given to other functions of the Fire Research Division which make it an effective service organization. These functions require that long-term programs be interrupted as the need arises to work on special problems and perform other services for the immediate advantage of fire control. The priorities established in the long-term program to be developed in this analysis will be modified to the extent necessary to meet these regional short-period needs.

Organization

Organization of the Experiment Station Fire Protection Research Division must play an important part in the development of a research program. The problems selected for study must be divided between the recognized research line projects, each concerned with a particular field of study. Those selected for planned attack must furthermore be susceptible to effective study by the available organization.

Line Projects. The field of forest fire protection research at the California Forest and Range Experiment Station is here considered to be divided into four line projects dealing with different but closely related technical aspects of the protection problem:

(1) The Control Project dealing with studies of protection agency activities and the development of better methods, practices, and equipment in the fields of prevention, presuppression, and suppression;

(2) The Behavior Project 1/ concerned with study of the physical relationships between the numerous forest fire behavior phenomena and their pertinent constant and variable controlling factors to provide factual information basic to the solution of problems in the control and effects fields;

(3) The Effects Project to which is assigned problems of evaluation of the destructible forest resources, the damages and benefits resulting from fires, and problems pertaining to the use of fire as a management tool;

(4) Economics dealing with all aspects of protection financing. 2/

1/ A problem analysis for the Fire Behavior Research Project at the California Forest and Range Experiment Station was prepared in 1938. Reference is made to that work for detailed material not contained in the present analysis of the general field. Any problem priorities established here in conflict with those previously determined, however, supersede those of the earlier date.

2/ Although Economics has never been granted project status in the Fire Division, this analysis has revealed a number of economic questions of importance in the fire control field which should eventually be given consideration either within the Division or in cooperation with the Division of Forest Economics.

Personnel and Facilities. The need for diversified attack on different aspects of various fire control problems was early recognized. There were phases of several control problems susceptible to direct attack, but at the same time it was evident that a knowledge of fire behavior phenomena was necessary to the solution of a number of major problems. Thus the Fire Research Division of the Experiment Station was led to a concentration of effort upon two projects, Behavior and Control. All personnel are at the present time engaged in studies in these fields with the distribution of individuals between them indicated below:

Behavior	Control
C. C. Buck (1/2)	C. C. Buck (1/2)
W. L. Fons	H. D. Bruce
R. W. Stromberg 3/	C. A. Abell
	R. K. Blanchard 4/

In addition to the personnel indicated, the Behavior Project is normally augmented during a portion of the summer field season by employment of two to four students or other temporary men. No short-term assistance is regularly available to the Control Project although a number of positions under Experiment Station supervision have been financed by the Region in the past, primarily in connection with cooperative pre-suppression planning projects.

Field experimental work in fire behavior is largely confined to the Shasta National Forest, designated as a fire experimental forest, in northern California. Experiment Station office and dormitory buildings are maintained at the Forest Supervisor's headquarters in Mount Shasta. A combination office-laboratory building at Pilgrim Creek Nursery east of McCloud serves as field headquarters for the behavior research personnel during the summer fire season. Both stations are closed during the winter months. The branch stations of other Research Divisions of the Experiment Station provide additional available facilities in various other parts of the state. In addition to these, numerous laboratory facilities are made available at Berkeley through the cooperation of various departments of the University of California.

3/ Indefinite appointment.

4/ Absent on two-year detail to Massachusetts Institute of Technology.

Long-term Research Program

Only a limited number of the major protection problems in California can be attacked by the present fire research organization with promise of solution within any reasonable long-term period. A planned research program, therefore, should be aimed specifically at the problems whose solutions are expected to yield the greatest protection benefits by the time that progress in fire control practice makes necessary a reevaluation of problem importances. The immediate task, then, is to select from the total number of problems those to which research can contribute the most within a reasonable time, and from these to select a few of higher priority for immediate attack. The preparation of detailed study plans is outside the scope of this analysis.

Classification of Problems. Few of the major fire protection problems are susceptible to solution as unit studies. In almost every case their solutions depend upon the results of a number of correlated studies in two or more line projects. In assigning research priorities to the problems it is therefore desirable to consider the part that each line project contributes to the complete solution of each problem. Another important consideration is the extent to which an individual study can be made to serve the needs of more than one problem. The scope of the studies should be such that their results may be generally applied to the solutions of all problems requiring similar information.

In setting up the basis upon which the research priorities have been established, therefore, all 77 problems have been broken down to show the kind and amount of research needed for their solutions. This break-down is presented in summary form in the accompanying table. In the analysis of the 77 major administrative problems the following six qualities have been considered: (1) the relative importance of the solution of each problem to fire control; (2) the number of kinds and interdependence of studies needed for solution of each problem; (3) susceptibility of the different parts of each problem to solution by the usual research methods; (4) limitations placed upon solutions by the availability of personnel, time, and facilities; (5) the present attack status of individual studies; and (6) whether a problem could best be treated by the Experiment Station or as an administrative study by the Region. In the table these six qualities were designated as follows:

(1) The relative importance of problems is shown by division of the table into three major parts designated high, medium, and low importance.

(2) The need for particular kinds of study is indicated by the presence of one or more code letters under the appropriate subdivisions of the respective line projects — Control, Behavior, Effects, and Economics. Dependence of the solution of any phase of a problem upon availability of basic information which must be supplied by other related studies is indicated by the letter L in the column for the field in which final solution belongs.

P R O B L E M S

PROBLEM
NUMBER

2. EFFECTIVENESS OF FIRE PREVENTION ACTIVITY AND OF INDIVIDUAL FIRE PREVENTION MEASURES.
9. THE RISK ACCOMPANYING DIFFERENT FIRE CAUSING AGENCIES.
10. THE PREVENTION MEASURES BEST SUITED TO COUNTERACTING THE FIRE STARTING HABITS OF FOREST USERS.
11. ROAD AND RIGHT-OF-WAY CONSTRUCTION AND MAINTENANCE SPECIFICATIONS TO MINIMIZE FIRE OCCURRENCE ALONG THE RIGHT-OF-WAYS.
12. SHORT TERM PREVENTION MEASURES BEST SUITED TO HIGH FIRE DANGER RESULTING FROM DIFFERENT CAUSES.
15. BEST METHOD OF RATING FIRE DANGER FOR USE IN PREVENTION WORK.
24. EQUIPMENT BEST SUITED TO THE DIFFERENT PRESUPPRESSION AND FIRE SUPPRESSION JOBS.
28. THE BEST BASIS FOR PLANNING THE DISTRIBUTION AND STRENGTH OF MANNING OF FIREMAN STATIONS, INCLUDING THE LOCATION AND ASSIGNMENT OF TANK TRUCKS.
29. THE BEST BALANCE BETWEEN INTENSITY OF PROTECTION AND THE FLUCTUATING NEED FOR PROTECTION.
32. TRAINING OF SHORT TERM PROTECTION PERSONNEL; INCLUDING APPRAISAL OF NEEDS, METHODS, AND EVALUATION OF THE EFFECTIVENESS.
33. TRAINING OF REGULAR PERSONNEL; INCLUDING EVALUATION OF THE NEEDS FOR TRAINING, METHODS OF TRAINING, AND SELECTION OF MEN FOR HIGHER TRAINING.
38. SECURING AN EFFICIENT BALANCE BETWEEN THE PROTECTION ACTIVITIES OF PREVENTION, PRESUPPRESSION, AND SUPPRESSION.
39. SECURING A BALANCED PRESUPPRESSION ORGANIZATION.
40. THE BEST PERSONNEL MANAGEMENT METHODS TO GET BETTER PERFORMANCE IN FIRE CONTROL.
45. THE NEEDS FIRE DANGER RATING MUST FILL AND THE BEST METHODS OF ESTIMATING FIRE DANGER FOR THESE PURPOSES.
46. THE NEEDS FIRE RECORDS MUST FILL AND THE BEST METHODS FOR COMPILING AND ANALYZING THE REQUIRED DATA.
48. THE FIRE SUPPRESSION OBJECTIVES AND POLICIES.
50. METHODS FOR PREDICTING AND INTEGRATING FIRE BEHAVIOR AND SUPPRESSION ACCOMPLISHMENT INFORMATION NECESSARY TO PROPER PLANNING OF FIRE STRATEGY.
51. PROVIDING INFORMATION AND DATA NECESSARY FOR PLANNING THE DETAILED TACTICAL OPERATIONS REQUIRED TO CARRY OUT THE SUPPRESSION JOB.
52. THE BEST METHODS FOR ACCOMPLISHING THE PHYSICAL JOBS OF LOCATING AND CONSTRUCTING FIRE LINES.
53. THE BEST METHODS FOR SECURING GREATEST MANPOWER EFFICIENCY IN "ON-THE-LINE" JOBS.
54. THE HAND AND POWER EQUIPMENT BEST SUITED TO THE DIFFERENT LINE OPERATIONS AND THE BEST TECHNIQUES OF USE.
56. DEVELOPMENT OF THE BEST PRINCIPLES, PRACTICES, AND EQUIPMENT FOR THE BACKFIRING JOB.
60. THE BEST METHODS FOR GATHERING AND DISSEMINATING NEEDED INFORMATION ON BEHAVIOR OF THE FIRE AND PROGRESS OF CONTROL OPERATIONS.
62. THE BEST METHODS FOR PREDICTING SUCH FIRE BEHAVIOR PHENOMENA AS SPREAD, CROWNING, SPOTTING, AND FINGERING WHICH INFLUENCE THE SUPPRESSION JOB.
67. THE BEST WAYS TO ORGANIZE AND OPERATE NEEDED SUPPRESSION COMMUNICATION FACILITIES.
68. THE NECESSARY FIRE RECORDS AND THE BEST METHODS FOR OBTAINING AND RECORDING THE REQUIRED INFORMATION.
69. SATISFACTORY METHODS FOR ESTIMATING FOREST VALUES.
70. THE BEST METHODS FOR MEASURING, ESTIMATING, AND PREDICTING THE DETRIMENTAL AND BENEFICIAL EFFECTS OF FIRES.
71. THE PLACE OF CONTROLLED BURNING IN THE MANAGEMENT OF THE FOREST AND RANGE LANDS OF CALIFORNIA.
72. THE PROPER EXPENDITURES FOR FIRE PROTECTION IN RELATION TO DEMONSTRABLE BENEFITS.
73. THE PUBLIC VALUES AT STAKE ON PRIVATE LANDS AND THEIR WORTH TO THE PUBLIC TO PROTECT THEM.

1. THE OBJECTIVES AND POLICIES OF FIRE PREVENTION WORK.
3. SUSCEPTIBILITY OF DIFFERENT FOREST FUELS TO IGNITION.
4. SPECIFICATIONS AND METHODS FOR FIREPROOFING LOGGING SLASH, RIGHT-OF-WAYS, CAMP GROUNDS, AND OTHER FOREST AREAS EXPOSED TO DIFFERENT KINDS OF USE.
7. THE RELATIVE PROBABILITY OF IGNITION OF FOREST FUELS BY DIFFERENT FIREBRANDS.
8. REDUCTION OF PROBABILITY OF IGNITION OF FOREST FUELS THROUGH ELIMINATION, MODIFICATION, OR CONTROL OF FIREBRANDS.
13. RELATION BETWEEN IGNITION PROBABILITY AND THE PHYSICAL CONDITIONS OF WEATHER, FUEL, TOPOGRAPHY, AND USE.
14. THE CONDITIONS UNDER WHICH FIRE MAY BE USED AS A MANAGEMENT TOOL WITHOUT UNDUE RISK TO ADJACENT FOREST AREAS.
18. THE NEED FOR SUPPLEMENTARY DETECTION AND THE BEST BASIS FOR PLANNING AN EMERGENCY DETECTION SYSTEM.
21. THE BEST BASIS FOR PLANNING A TRANSPORTATION SYSTEM FOR FOREST PROTECTION PURPOSES.
31. MAINTAINING PHYSICAL FITNESS AND GENERAL EFFICIENCY OF PROTECTION PERSONNEL.
35. DEVELOPMENT OF FIRE SUPPRESSION PLANS AS A PRESUPPRESSION ACTIVITY WHICH WILL MAKE SUBSEQUENT FIRE SUPPRESSION ACTION MOST EFFICIENT.
37. EQUITABLE DISTRIBUTION OF FIRE CONTROL ALLOTMENTS BETWEEN PROTECTION UNITS.
41. THE MANNER IN WHICH VALUES, THEIR OWNERSHIP, AND THEIR SUSCEPTIBILITY TO DAMAGE AFFECT THE INTENSITY OF NECESSARY FIRE PROTECTION.
42. THE MANNER IN WHICH PROBABLE FIRE OCCURRENCE AFFECTS THE INTENSITY OF NECESSARY FIRE PROTECTION AND CORRESPONDING PRESUPPRESSION ACTIVITY.
43. THE MANNER IN WHICH PROBABLE RATE OF SPREAD AFFECTS THE INTENSITY OF NECESSARY FIRE PROTECTION AND CORRESPONDING PRESUPPRESSION ACTIVITY.
44. THE MANNER IN WHICH DIFFICULTY OF CONTROL AFFECTS THE INTENSITY OF NECESSARY FIRE PROTECTION AND CORRESPONDING PRESUPPRESSION ACTIVITY.
47. ADOPTION OF UNIFORM METHODS OF REPORTING AND COMPILING FOREST FIRE DATA BY THE DIFFERENT PROTECTION AGENCIES.
59. THE BEST FIRE FIGHTING TECHNIQUES FOR HANDLING SPOTTING, CROWNING, AND FINGERING.
61. THE BEST METHODS FOR DETERMINING NEEDED STRENGTH AND DURATION OF MANNING A FIRE FOLLOWING CONTROL.
63. THE STRUCTURE AND MANAGEMENT OF THE OVERHEAD ORGANIZATION WHICH WILL MEET THE SUPPRESSION NEEDS OF LARGE FIRES MOST EFFICIENTLY.
64. THE BEST PRINCIPLES AND METHODS OF CAMP MANAGEMENT TO INSURE MAXIMUM NUMBERS AND EFFICIENCY OF MEN ON THE FIRE LINE.
74. IMPROVEMENT AND EXTENSION OF FOREST AND FIRE LAWS FOR BETTER AND CHEAPER FIRE PROTECTION.
76. EQUITABLE DISTRIBUTION OF COST OF PROTECTION BY FOREST TAX ADJUSTMENTS.
77. FOREST FIRE INSURANCE FOR PRIVATE FOREST OWNERS.

5. REDUCTION OF FOREST IGNITIBILITY, RATE OF FIRE SPREAD, AND DIFFICULTY OF CONTROL THROUGH MODIFICATION OF SILVICULTURAL, LOGGING, AND GRAZING PRACTICES.
6. EQUIPMENT TO MEET HAZARD REDUCTION NEEDS.
16. DETECTION STANDARDS REQUIRED TO MEET VARYING HOUR CONTROL NEEDS.
17. THE BEST BASIS FOR PLANNING PRIMARY LOOKOUT DETECTION SYSTEMS.
19. IMPROVEMENT OF STRUCTURES AND EQUIPMENT FOR INCREASING THE EFFICIENCY OF LOOKOUT DETECTION.
20. THE BEST BASIS FOR PLANNING COMMUNICATION SYSTEMS FOR FOREST PROTECTION PURPOSES.
22. THE PROPER ROLE OF FIREBREAKS IN FOREST PROTECTION AND THE BEST BASIS FOR PLANNING A FIREBREAK SYSTEM.
23. THE BEST METHODS FOR SECURING WATER STORAGE FACILITIES FOR SUPPRESSION PURPOSES.
25. THE BEST SYSTEM FOR APPORTIONING FIRE EQUIPMENT AMONG DIFFERENT PROTECTION UNITS.
26. THE BEST METHODS FOR FINANCING, SERVICING, AND MAINTAINING FIRE EQUIPMENT.
27. THE BEST METHODS FOR WAREHOUSING AND PACKAGING OF FIRE EQUIPMENT.
30. REDUCTION IN LARGE TURNOVER IN SHORT TERM PERSONNEL.
34. SECURING THE COOPERATION WHICH WILL RESULT IN MOST EFFICIENT PROTECTION.
36. THE EXTENT TO WHICH THE PROTECTION WORK OF DIFFERENT AGENCIES SHOULD BE COORDINATED TO SECURE MAXIMUM PROTECTION AT LOWEST TOTAL COST.
49. THE BEST METHODS FOR MOBILIZING AND DISPATCHING MANPOWER AND EQUIPMENT FOR FIRE SUPPRESSION.
55. SAFETY PRINCIPLES, PRACTICES, AND EQUIPMENT BEST SUITED TO REQUIREMENTS OF THE SUPPRESSION JOB.
57. THE BEST TECHNIQUES FOR LINE HOLDING.
58. THE BEST TECHNIQUES FOR PATROL AND MOP-UP.
65. THE BEST METHODS FOR HANDLING AND SERVICING FIRE FIGHTING TOOLS AND EQUIPMENT ON GOING FIRES.
66. ECONOMICAL AND EXPEDITIOUS TRANSPORTATION OF MEN, EQUIPMENT AND SUPPLIES ON FIRES.
75. THE PORTION OF THE SUBSEQUENT INCREASED COST OF PROTECTION THAT LOGGING OPERATORS SHOULD BEAR.

RELATIVE IMPORTANCE	PROBLEM NUMBER	CONTROL			BEHAVIOR								EFFECTS			ECONOMICS	PROBLEM NUMBER
		PREVENTION	PRESUPPRESSION	SUPPRESSION	SAMPLING AND MEASURING CONTROLLING VARIABLES	PROBABILITY OF IGNITION	RATE OF INITIAL SPREAD	RATE OF SPREAD OF LARGE FIRES	CROWNING, SPOTTING, FINGERING ETC.	BEHAVIOR OF CONTROLLED FIRES	BEHAVIOR OF BACKFIRES	FIRE INTENSITY	FOREST VALUES	FIRE EFFECTS	CONTROLLED BURNING	FIRE CONTROL ECONOMICS	
	2	DZ	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
	9	B	....	....	....	....	....	....	....	....	....	....	....	....	....	....	9
	10	FDLZ	....	....	....	....	....	....	....	....	....	....	B	B	B	....	10
	11	....	....	....	A	A	....	....	....	....	....	....	....	....	....	....	11
	12	CL	....	....	B	B	....	....	....	....	....	....	....	....	....	....	12
	15	BL	....	....	BN	BN	....	....	....	....	....	....	....	....	....	....	15
	24	....	FAY	....	....	....	....	....	....	....	....	....	....	....	....	....	24
	28	....	ANLY	....	AN	A	ANY	....	....	....	....	....	A	AY	....	....	28
	29	....	BNLY	....	AN	AN	ANY	....	....	....	....	....	....	AY	....	....	29
	32	....	FAZ	....	....	....	....	....	....	....	....	....	....	....	....	....	32
	33	....	FAZ	....	....	....	....	....	....	....	....	....	....	....	....	....	33
	38	....	BL	....	BN	BNY	BNY	BNY	....	....	....	....	....	B	....	B	38
	39	....	BNLY	....	BN	....	BN	....	....	....	....	....	B	B	....	....	39
	40	....	FB	....	....	....	....	....	....	....	....	....	....	....	....	....	40
	45	....	BNLY	....	AN	AN	ANY	....	....	....	....	....	....	....	....	....	45
HIGH	46	....	ANL	....	A	....	....	....	....	....	....	....	A	AY	....	A	46
	48	....	....	AL	....	....	AN	BN	C	C	A	....	A	A	....	C	48
	50	....	....	ANLY	A	....	....	ANY	BY	C	B	....	A	A	....	....	50
	51	....	....	ALY	AN	....	....	ANY	BY	C	B	BY	....	....	....	....	51
	52	....	....	A	....	....	....	....	....	....	....	....	....	....	....	....	52
	53	....	....	A	....	....	....	....	....	....	....	....	....	....	....	....	53
	54	....	....	FA	....	....	....	....	....	....	....	....	....	....	....	....	54
	56	....	....	AL	AN	....	....	....	....	....	B	....	....	A	....	....	56
	60	....	....	AN	....	....	....	....	....	....	....	....	....	....	....	....	60
	62	....	....	....	AN	....	ANY	BNY	CY	C	B	B	....	....	....	....	62
	67	....	....	FBN	....	....	....	....	....	....	....	....	....	....	....	....	67
	68	....	....	AN	AN	....	....	....	....	....	....	....	....	A	....	....	68
	69	....	....	....	....	....	....	....	....	....	....	....	B	....	....	....	69
	70	....	....	....	A	....	....	....	....	....	....	DY	....	BLY	....	....	70
	71	....	....	....	AN	....	....	AY	BY	....	....	DY	....	ALY	ALY	C	71
	72	....	....	....	....	....	....	....	....	....	....	....	....	....	....	FB	72
	73	....	....	....	....	....	....	....	....	....	....	....	B	B	....	DL	73
	1	FDL	....	....	....	....	....	....	....	....	....	....	B	B	....	B	1
	3	....	....	....	A	A	....	....	....	....	....	....	....	....	....	....	3
	4	ANL	....	....	A	A	A	....	....	....	....	....	....	....	A	....	4
	7	....	....	....	A	AN	....	....	....	....	....	....	....	....	....	....	7
	8	AL	....	....	A	A	....	....	....	....	....	....	....	....	....	....	8
	13	....	....	....	AN	AN	....	....	....	....	....	....	....	....	....	....	13
	14	AL	....	....	AN	AY	ANY	AY	BY	....	....	AY	....	....	A	....	14
	18	....	ANL	....	AN	....	AN	....	....	....	....	....	....	....	....	....	18
	21	....	ANL	....	AN	....	ANY	....	....	....	....	....	A	AY	....	....	21
	31	....	FAZ	....	....	....	....	....	....	....	....	....	....	....	....	....	31
	35	....	ASLY	....	AN	....	ANY	ANY	BY	CY	B	....	B	B	....	....	35
MEDIUM	37	....	BL	....	B	....	B	B	....	....	....	....	B	B	....	B	37
	41	....	BLY	....	....	....	....	....	....	....	....	....	B	B	....	....	41
	42	....	BNLY	....	....	B	....	....	....	....	....	....	....	....	....	....	42
	43	....	BNLY	....	....	....	BN	BN	....	....	....	....	....	....	....	....	43
	44	....	BSY	....	B	....	....	....	....	....	....	....	....	....	....	....	44
	47	....	F	....	....	....	....	....	....	....	....	....	....	....	....	....	47
	59	....	....	ALY	A	....	....	....	BY	....	....	....	....	....	....	....	59
	61	....	....	DL	D	....	....	....	....	C	....	....	....	....	....	....	61
	63	....	....	FAS	....	....	....	....	....	....	....	....	....	....	....	....	63
	64	....	....	FAS	....	....	....	....	....	....	....	....	....	....	....	....	64
	74	....	....	....	....	....	....	....	....	....	....	....	....	....	....	FC	74
	76	....	....	....	....	....	....	....	....	....	....	....	B	B	....	DL	76
	77	A	A	....	A	A	....	....	....	....	....	....	A	A	....	AL	77
	5	BL	A	....	BY	BY	BY	....	....	....	....	B	....	....	....	....	5
	6	FAN	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6
	16	....	ANL	....	AN	....	BN	....	....	....	....	....	....	....	....	....	16
	17	....	ANL	....	....	....	....	....	....	....	....	....	B	B	....	....	17
	19	....	FAS	....	....	....	....	....	....	....	....	....	....	....	....	....	19
	20	....	FAS	....	....	....	....	....	....	....	....	....	....	....	....	....	20
	22	....	AL	....	A	....	....	A	A	....	A	A	....	....	....	....	22
	23	....	FAS	....	....	....	....	....	....	....	....	....	....	....	....	....	23
	25	....	BL	....	....	....	....	....	....	....	....	....	B	B	....	....	25
LOW	26	....	FB	....	....	....	....	....	....	....	....	....	....	....	....	....	26
	27	....	FA	....	....	....	....	....	....	....	....	....	....	....	....	....	27
	30	....	FB	....	....	....	....	....	....	....	....	....	....	....	....	....	30
	34	....	F	....	....	....	....	....	....	....	....	....	....	....	....	....	34
	36	....	FB	....	....	....	....	....	....	....	....	....	....	....	....	B	36
	49	....	....	A	....	....	....	....	....	....	....	....	....	....	....	....	49
	55	....	....	BL	A	....	....	B	B	....	B	....	....	....	....	....	55
	57	....	....	A	....	....	....	....	....	....	B	B	....	....	....	....	57
	58	....	....	A	A	....	....	....	....	C	....	....	....	....	....	....	58
	65	....	....	FA	....	....	....	....	....	....	....	....	....	....	....	....	65
	66	....	....	FA	....	....	....	....	....	....	....	....	....	....	....	....	66
	75	....	....	....	....	....	....	....	....	....	....	....	....	....	....	B	75

LEGEND

A - CONSIDERABLE PROMISE OF DEFINITE RESULTS
B - CONSIDERABLE PROMISE OF PARTIAL RESULTS
C - SOME PROMISE OF DEFINITE RESULTS
D - SOME PROMISE OF PARTIAL RESULTS
F - RESERVED FOR ADMINISTRATIVE STUDY

L - ULTIMATE SOLUTION REQUIRES BASIC RESEARCH
N - PRESENT WORK
S - SOME WORK IN PAST DECADE, DISCONTINUED
Y - LONG TERM STUDY, 10 YEARS OR MORE
Z - REQUIRES SPECIALIST, NOT AVAILABLE

(3) The susceptibility to solution of those phases of each problem for which the respective line projects are responsible is shown by the code letters A, B, C, D, in the proper column. Two criteria have been employed in estimating susceptibility ratings: (1) the probability that a satisfactory solution can be derived by present research methods irrespective of the agency performing the study, and (2) the completeness of the anticipated solution in fulfilling fire protection needs. It should be reemphasized that "solution" here refers to the results of a technical study. Application of these results in bettering fire protection practices on a large scale is an administrative function and is not considered a part of the research solution.

(4) Where solution of the problem requires extended time, or specialized personnel not now available, these are indicated by Y or Z, respectively. A period in excess of 10 years is here generally considered to be extended time.

(5) The current attack status of individual studies is indicated by N for going studies in the current research program, and by S for studies undertaken within the past decade but discontinued with or without completion.

(6) Some problems in each importance group are designated for administrative study, either because solution is largely dependent upon administrative policy, or because the administrative organization is equipped with personnel and facilities well suited to the study of the problem. These are distinguished by the symbol F.

An illustration of the manner in which problem characteristics are indicated in the table may be obtained by following through Problem 28, "The best basis for planning the distribution and strength of manning of fireman stations, including the location and assignment of tank trucks".

This problem occurs in the high importance group.

The occurrence of code letters in different columns of the table opposite Problem 28 indicates that ultimate solution requires appropriate study of presuppression aspects in the Control project, studies of sampling and measuring variables, and of ignition and initial rates of spread in the Behavior project, also studies of forest values and of fire effects in the Effects project.

The code letter A in each column indicates that the chances of a definite solution are good in all instances where research study is involved.

In the presuppression column, N L Y indicates that one or more going studies relate to this phase of the problem, that ultimate solution of this portion requires basic information in behavior and effects, and that solution of the presuppression aspects of the problem will probably not be completed within 10 years because of the time required to obtain the necessary basic information in Behavior and Effects.

N in the first Behavior column indicates that one or more sampling and measuring studies now under way in the fire behavior project will aid in solving Problem 28. A alone in the second Behavior column indicates the need for studies of fire ignition that would require probably less than 10 years, but are not now under investigation. N Y in the third column indicates that current studies of the initial rates of spread of fires, pertinent to the problem, will require in excess of 10 years.

A alone in the first Effects column indicates the need for pertinent study of forest values requiring probably less than 10 years, but not active at present. Y in the second Effects column indicates the need for long-term studies of fire effects, but which are not now under investigation.

Selection of Research Problems. It is impractical at this time to include in a work program all of the major fire protection problems considered susceptible to study by the Experiment Station. It was deemed advisable, then, to select from the 77 problems those which could be expected to enter into the research program within a reasonably long-term period, to indicate the few of this selected group that are most in need of immediate attack, and finally to eliminate from these problems the ones which must be postponed because of lack of personnel.

The first step was to eliminate all low and medium importance problems from consideration for the planned research program. The table on the following page is thus a recapitulation of the remaining 24 high importance problems which are considered susceptible to Experiment Station attack — that is, with the problems designated for administrative study omitted, as well as those of medium and low importance. These 24 problems will constitute the long-term fire research program at the California Station. Problems in the medium and low importance group will be undertaken for study only as special short period assignments may be justified by unforeseen circumstances.

The selection of problems of high research priority from the 24 which constitute the basic program has been made largely on the basis of two considerations: (1) the generally recognized outstanding importance of some of the problems, and (2) the need for solving some problems first to secure information necessary for the orderly solution of others. On this basis 13 problems are considered of high research priority and in immediate need of attack. These are distributed among the four major protection activities as follows:

High Research Priority Problems

Prevention	Presuppression	Suppression	Effects
	Problem numbers		
2	28	50	69
12	29	51	70
	39	53	71
	45	62	

PROBLEMS

PROBLEM NUMBER

2. EFFECTIVENESS OF FIRE PREVENTION ACTIVITY AND OF INDIVIDUAL FIRE PREVENTION MEASURES.
9. THE RISK ACCOMPANYING DIFFERENT FIRE CAUSING AGENCIES.
11. ROAD AND RIGHT-OF-WAY CONSTRUCTION AND MAINTENANCE SPECIFICATIONS TO MINIMIZE FIRE OCCURRENCE ALONG THE RIGHT-OF-WAYS.
12. SHORT TERM PREVENTION MEASURES BEST SUITED TO HIGH FIRE DANGER RESULTING FROM DIFFERENT CAUSES.
15. BEST METHOD OF RATING FIRE DANGER FOR USE IN PREVENTION WORK.

28. THE BEST BASIS FOR PLANNING THE DISTRIBUTION AND STRENGTH OF MANNING OF FIREMAN STATIONS, INCLUDING THE LOCATION AND ASSIGNMENT OF TANK TRUCKS.
29. THE BEST BALANCE BETWEEN INTENSITY OF PROTECTION AND THE FLUCTUATING NEED FOR PROTECTION.
38. SECURING AN EFFICIENT BALANCE BETWEEN THE PROTECTION ACTIVITIES OF PREVENTION, PRESUPPRESSION, AND SUPPRESSION.
39. SECURING A BALANCED PRESUPPRESSION ORGANIZATION.
45. THE NEEDS FIRE DANGER RATING MUST FILL AND THE BEST METHODS OF ESTIMATING FIRE DANGER FOR THESE PURPOSES.

46. THE NEEDS FIRE RECORDS MUST FILL AND THE BEST METHODS FOR COMPILING AND ANALYZING THE REQUIRED DATA.
48. THE FIRE SUPPRESSION OBJECTIVES AND POLICIES.
50. METHODS FOR PREDICTING AND INTEGRATING FIRE BEHAVIOR AND SUPPRESSION ACCOMPLISHMENT INFORMATION NECESSARY TO PROPER PLANNING OF FIRE STRATEGY.
51. PROVIDING INFORMATION AND DATA NECESSARY FOR PLANNING THE DETAILED TACTICAL OPERATIONS REQUIRED TO CARRY OUT THE SUPPRESSION JOB.
52. THE BEST METHODS FOR ACCOMPLISHING THE PHYSICAL JOBS OF LOCATING AND CONSTRUCTING FIRE LINES.

53. THE BEST METHODS FOR SECURING GREATEST MANPOWER EFFICIENCY IN "ON-THE-LINE" JOBS.
56. DEVELOPMENT OF THE BEST PRINCIPLES, PRACTICES, AND EQUIPMENT FOR THE BACKFIRING JOB.
60. THE BEST METHODS FOR GATHERING AND DISSEMINATING NEEDED INFORMATION ON BEHAVIOR OF THE FIRE AND PROGRESS OF CONTROL OPERATIONS.
62. THE BEST METHODS FOR PREDICTING SUCH FIRE BEHAVIOR PHENOMENA AS SPREAD, CROWNING, SPOTTING, AND FINGERING WHICH INFLUENCE THE SUPPRESSION JOB.
68. THE NECESSARY FIRE RECORDS AND THE BEST METHODS FOR OBTAINING AND RECORDING THE REQUIRED INFORMATION.

69. SATISFACTORY METHODS FOR ESTIMATING FOREST VALUES.
70. THE BEST METHODS FOR MEASURING, ESTIMATING, AND PREDICTING THE DETRIMENTAL AND BENEFICIAL EFFECTS OF FIRES.
71. THE PLACE OF CONTROLLED BURNING IN THE MANAGEMENT OF THE FOREST AND RANGE LANDS OF CALIFORNIA.
73. THE PUBLIC VALUES AT STAKE ON PRIVATE LANDS AND THEIR WORTH TO THE PUBLIC TO PROTECT THEM.

CLASSIFICATION OF HIGH PRIORITY FIRE PROTECTION PROBLEMS IN CALIFORNIA IN NEED OF RESEARCH

	CONTROL			BEHAVIOR								EFFECTS			ECONOMICS	
PROBLEM NUMBER	PREVENTION	PRESUPPRESSION	SUPPRESSION	SAMPLING AND MEASURING CONTROLLING VARIABLES	PROBABILITY OF IGNITION	RATES OF INITIAL SPREAD	RATES OF SPREAD OF LARGE FIRES	CROWNING, SPOTTING FINGERING, ETC.	BEHAVIOR OF CONTROLLED FIRES	BEHAVIOR OF BACKFIRES	FIRE INTENSITY	FOREST VALUES	FIRE EFFECTS	CONTROLLED BURNING	FIRE CONTROL ECONOMICS	PROBLEM NUMBER
2	DZ	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
9	B	....	....	....	....	....	....	....	....	....	....	....	....	....	....	9
11	....	....	....	A	A	....	....	....	....	....	....	....	....	....	....	11
12	CL	....	....	B	B	....	....	....	....	....	....	....	....	....	....	12
15	BL	....	....	B	B	....	....	....	....	....	....	....	....	....	....	15
28	....	ANLY	....	AN	A	ANY	....	....	....	....	....	A	AY	....	....	28
29	....	BNLY	....	AN	AN	ANY	....	....	....	....	....	....	AY	....	....	29
38	....	BL	....	BN	BNY	BNY	BNY	....	....	....	....	....	B	....	B	38
39	....	BNLY	....	BN	....	BN	....	....	....	....		B	B	....	....	39
45	....	BNLY	....	AN	AN	ANY	....	....	....	....	....	....	....	....	....	45
46	....	ANL	....	A	....	....	....	....	....	....	....	A	AY	....	A	46
48	....	....	AL	....	....	AN	BN	C	C	A	....	A	A	....	C	48
50	....	....	ANLY	A	....	....	ANY	BY	C	B	....	A	A	....	....	50
51	....	....	ALY	AN	....	....	ANY	BY	C	B	BY	....	....	....	....	51
52	....	....	A	....	....	....	....	....	....	....	....	....	....	....	....	52
53	....	....	A	....	....	....	....	....	....	....	....	....	....	....	....	53
56	....	....	AL	AN	....	....	....	....	....	B	....	....	A	....	....	56
60	....	....	AN	....	....	....	....	....	....	....	....	....	....	....	....	60
62	....	....	....	AN	....	ANY	BNY	CY	C	B	B	....	....	....	....	62
68	....	....	AN	AN	....	....	....	....	....	....	....	....	A	....	....	68
69	....	....	....	....	....	....	....	....	....	....	....	B	....	....	....	69
70	....	....	....	A	....	....	....	....	....	....	DY	....	BLY	....	....	70
71	....	....	....	AN	....	....	AY	BY	....	....	DY	....	ALY	ALY	C	71
73	....	....	....	....	....	....	....	....	....	....	....	B	B	....	DL	73

LEGEND

A - CONSIDERABLE PROMISE OF DEFINITE RESULTS
B - CONSIDERABLE PROMISE OF PARTIAL RESULTS
C - SOME PROMISE OF DEFINITE RESULTS
D - SOME PROMISE OF PARTIAL RESULTS

N - PRESENT WORK
L - ULTIMATE SOLUTION REQUIRES BASIC RESEARCH
Y - LONG TERM STUDY, 10 YEARS OR MORE
Z - REQUIRES SPECIALIST, NOT AVAILABLE

Consideration of the capacity of the present research organization of the Fire Division of the California Station, the qualifications of its personnel, research objectives and policies, and the characteristics of the individual problems indicated in the previous tables has resulted in eliminating from the selected 13 high research priority problems those five pertaining to fire prevention and fire effects. Although it is generally recognized that fire effects studies should be undertaken immediately, it is also recognized that little major accomplishment could be made without withdrawing from present productive studies. The 8 remaining problems, solutions of which depend primarily on research in the projects of Behavior and Control, are thus of top priority in the research program and are proposed for study in the immediate future.

<u>Summary of Top Priority Problems in the California Forest and Range Experiment Station Long-term Fire Research Program Proposed for Study in the Near Future.</u>

<u>Number</u>

28. The best basis for planning the distribution and strength of manning of fireman stations, including the location and assignment of tank trucks.

29. The best balance between intensity of protection and the fluctuating need for protection.

39. Securing a balanced presuppression organization.

45. The needs fire danger rating must fill and the best methods of estimating fire danger for those purposes.

50. Methods for predicting and integrating fire behavior and suppression accomplishment information necessary to proper planning of fire strategy.

51. Providing information and data necessary for planning the detailed tactical operations required to carry out the suppression job.

53. Best methods for securing greatest manpower efficiency in "on-the-line" jobs.

62. The best methods for predicting those fire behavior phenomena such as rate of spread, crowning, spotting and fingering which influence the suppression job.

The fire research program of the California Station is made up of studies each aimed toward solution of some part of a major protection problem. In most instances these studies correspond in scope to questions presented under the 77 major problems in Section III of this analysis. It has already been made apparent that unit jobs much narrower than the broad problems are desirable for the research approach.

The current studies of the Fire Protection Division are shown in the accompanying table.[5/] It will be noted that all studies are expected to contribute to the solution of several major problems. Accordingly, the program is aimed in general in the right direction. However, in the light of existing knowledge and the present status of fire control needs, a redirection of emphasis upon the most important major problems is required. Hence the problems toward which the program will be directly pointed in the near future are numbers 28, 29, 39, 45, 50, 51, 53, and 62.

Some adjustments of the present program are needed to effect the required changes. Studies that are out of line will be abandoned as soon as sufficient benefits can be derived that the work invested will not be wasted. Efficient endeavor appears to demand the concentration of effort on a small number of studies rather than the dissipation of available resources over a broad field. Hence, no new work will be undertaken until present studies on problems in the low importance group can be brought to logical stopping points. The time allotments estimated as adequate to bring these studies to a close within a reasonable period are indicated in the table showing current studies.

The studies which will make up the subsequent program are not being scheduled at this time beyond indicating that they will be in the fields of Behavior and Control delineated by the eight highest priority problems previously enumerated. Rigid programs of individual studies have been upset in the past rather quickly by variations in research results, in national and regional emphasis on particular problems, and in opportunities for effective study. Study schedules for the active line projects are, therefore, planned for only short periods. These short period programs are governed by the extent to which current analyses show that the individual studies can contribute most to the more important problems and by opportunity for productive, concentrated study. Through these means the program can be kept flexible enough to meet current demands of fire control and yet maintain the continuity of effort required for productive research.

5/ Reference individual project status sheets in current annual report for details of purpose, status, etc., of each current study.

Current Studies in the California Fire Protection Research Program

Current studies	Problems to which study contributes: High importance	Problems to which study contributes: Medium and low importance	Time available (percent of each man's total): Buck	Fons	Stromberg	Field Ass'ts 1/	Bruce	Abell	Blanchard
BEHAVIOR			60						
Wind Velocity	45,50,51,62,68	13,14,35		5	20	5			5
Moisture content	45,50,51,56,62,68	13,14,35		10	30	5			5
Forest fuels	28,39,45,50,51,56,62,68,71	4,13,14,21,35		40	15	50			5
Fire ignition	29,45	4,7,13		10	10	5			5
Test fires	28,38,39,45,62	16,18,21,35,43		20	20	10			
Large fire behavior	38,48,50,51,62	14,21,35		10	5			10	
CONTROL			40						
Chemical control vegetation		4,6					20		
Radius of vision	15,29,45	16,17,18,34					30		
Use of water and chemicals	50,53	44,57,58,59					50		
Fire danger rating	15,29,45	42,43		5				10	80
Rate of line construction	28,50,51,52,53								
Firebreaks	28,50,51	22						25	
Southern California detection	29,38	16,17						25	
Suppression organization	60,67	63							
Statistics	28,46,68							30	
			100	100	100	75	100	100	100

1/ Total field assistants = 9 man-months per year